The Journal
Hyderabad Geological Survey

Vol. III. Part 1.

CONTENTS

Government Central Press
Hyderabad-Deccan. 1936

Price O.S. Rs. 4/12 ; *B.G. Rs.* 4/—

CONTENTS

SECTION A.

GEOLOGY OF THE EASTERN PORTION OF THE RAICHUR DO-AB WITH SPECIAL REFERENCE TO THE GRANODIORITIC PHASE OF THE DHARWAR SERIES OF ROCKS.

SECTION B.

SECTION C.

PLATES.

MAP.

PUBLICATIONS OF THE HYDERABAD GEOLOGICAL SURVEY.

Errata

1. Read '*Junction*' for 'Juncttion', page 75, line 7
2. Read '*Emitted*' for 'omitted', page 77, line 11
3. Read '*Figure 1, Plate X*' for 'Figure 1' page 88, line 30

SECTION A.

Geology of the Eastern portion of the Raichur Do-ab with Special Reference to the Granodioritic Phase of the Dharwar Series of Rocks.

Introduction.

THE geology of the western portion of the Raichur Do-ab has been discussed at length in Vol. II pt. i of the Journal, Hyderabad Geological Survey. Subsequent to the completion of that work, the attention of the Geological Survey Department was directed to the mapping of the area in the Do-ab east of Long. 77° up to the junction of the Kistna and Tungabhadra rivers. Thus, the area included in this report consists of the country east of Long. 77°, bounded in the North and the South by the Kistna and the Tungabhadra rivers respectively, constituting roughly the eastern half of the Raichur District. The total area thus covered in the report is about 2,088 square miles.

A composite geological map (*Vide* Map No. 2, Geological Map of the Eastern Portion of the Raichur Do-ab) of this tract of country is prepared from Survey of India sheets, Nos. 56, D, H, L, 57, A, E and I on scale 1″=4 miles.

Co-ordinate system of map reference.

For ready reference to find the villages on the map and avoid the use of latitude and longitude readings, the following co-ordinate system has been adopted, when a village is mentioned for the first time. The map is divided into 24 main squares by the latitude and longitude lines for every 15′. These squares have been numbered A to E horizontally and 3 to 1 vertically. So each main square will be referred to thus :—A. 3. Each of these main squares is then considered to be sub-divided into 81 squares by dividing the horizontal and vertical lines each into 9 equal divisions. For purposes of reference, the bottom left corner of each main square is to be considered as zero. The first index will represent the horizontal and

the second the vertical co-ordinate. For example, Manvi (A. 3 ; 2.9) ; here, A refers to the horizontal and 3 to the vertical reading of the main square, and 2 to the horizontal and 9 to the vertical co-ordinates of the subsidiary square. A transparent squared paper is supplied with the map to facilitate reference by superposition on any of the big squares of the map. The co-ordinates of the villages are given in footnotes.

Topography. The topography of a country is the physical expression of its geology. This fact is typified in the area under review. In conformity with the complexity of geological formations, we get a variety of topographic features, marking the country from end to end. Thus, undulating black cotton-soil strips, cut by numerous nullahs, characterise the country of the Dharwar schists which is now, due to improvidence of the ryot, practically denuded of trees and presents a monotonous landscape. The gneissic country is generally more or less broken and covered with a thin mantle of red loamy soil. Gneissic hills, where they occur, form bold reliefs in the landscape. The sedimentary formations which occupy the small belt of country adjoining the confluence of the Kistna and the Tungabhadra rivers occupy more or less flat plateaus.

Hills. Regionally viewed, the hills in the area present some structural features which are of interest in relation to the geology of the area.

(1) Taking the most south-westerly group, the hills of Hardiguda,[1] Manvi[2] (1836′) and Rubanakallu[3] show a continuity along a roughly N.W.-S.E. direction.

(2) From Sirvar[4] (1616′) and Yeramsar[5] (1505′), running in a roughly S.E. trend, may be recognised the hills of Madugeri[6] (1320′), Nirmanvi,[7] Gorkal[8] (1523′) Kurvi[9] (1609′) and 1504′ hill 2 miles west of Kamalahatti.[10]

1. Hardiguda (A. 2 ; 1.2). 2. Manvi (A. 3 ; 2.9). 3. Rubanakallu (A. 3 ; 3.8). 4. Sirvar (A. 2 ; 1.7). 5. Yeramsar (A. 2 ; 1.8). 6. Madugeri (A. 2 ; 3.4). 7. Nirmanvi (A. 2 ; 4.2). 8. Gorkal (A. 2; 7.1). 9. Kurvi (A. 3 ; 4.9). 10. Kamalahatti (A. 3 ; 8.9).

(3) Between Masarkal[1] (1774′) and Gabur[2] (1506′) a number of gneissic hills are seen at Kakargal,[3] Jinapur[4], Hangundabad[5] (1510′), Ramdrug[6], Jagatkal,[7] Khardigud[8] (1515′) Maladkal[9] and Gabur (1506′). The hills around Uttanur[10] are seen to be in line with the south-western group of hillocks in the above area. In the schist band itself, the isolated hills of Ganekal[11] and Nilagal[12] as also the hill clusters around Kalmali[13] and Kallur[14] are seen to be situated in the same N.W.-S.E. strike disposition as of that of the group of gneissic hills enumerated above.

(4) The hills around Raichur[15] which constitute a prominent landmark in the area may be also seen roughly to display a N.W.-S.E. trend. The significance of this structural feature to the geology of the area will be pointed out in the subsequent pages.

River-system.

The Kistna river flows in the area under report in a general W.N.W.-E.S.E. direction till it meets the Tungabhadra. The Tungabhadra has a N.E. trend as it enters the western portion of the area. After flowing in this direction for about 10 miles it turns eastwards and making a small loop near Kurnool, the river flows N.E. again to join the Kistna at Arlapadu[16]. The general slope of the country is from W.N.W.-E.S.E.

Tributaries.

Two distinct systems of tributaries feed the two rivers, the group flowing into the Kistna has a north to N.E. trend and that emptying into the Tungabhadra a S.S.E. disposition.

The watershed of the area is roughly the 1300 ft. contour and corresponds generally with the high ground

1. Masarkal (A. 1; 1.5). 2. Gabur (A. 1; 6.3). 3. Kakargal (A. 1; 2.4). 4. Jinapur (A. 1; 3.3). 5. Hangundabad (A. 1; 1.2). 6. Ramdrug (A. 1; 3.2). 7. Jagatkal (A. 1; 2.1). 8. Khardigud (A. 1; 3.1). 9. Maladkal (A. 1; 4.2). 10. Uttanur (A. 2; 4.7). 11. Ganekal (A. 2; 5.9). 12. Nilagal (A. 2; 5.8). 13. Kalmali (A. 2; 8.8). 14. Kallur (A. 2; 8.6). 15. Raichur (B. 2; 4.8). 16. Arlapadu (Lat. 15.59/ Long. 78 .16).

on which the Raichur-Lingsugur road is laid. East of the Railway line the watershed continues in the same direction. Streams to the south of this water-parting empty into the Tungabhadra and those to the north join the Kistna river.

The hill systems in the area were divided into three groups west of the Railway line. In conformity with this division, the main streams occupy the valleys between these three hill systems.

A reference to the map (*Vide* Map No. 2) brings out these features clearly.

GEOLOGICAL FORMATIONS

The geological formations met with in the area may be classed under the following heads :—

(I) The Dharwar System consisting of

- (1) Chlorite schists.
- (2) Hornblende schists.
- (3) Trappoid diabasic schists.
- (4) Granodioritic rocks.

} *Dharwars.*

(II) Peninsular Gneissic Complex represented by

- (1) Grey series of gneisses and their acidic representatives.
- (2) Pink series of gneisses and their acidic representatives.
- (3) Red syenites.

(III) Dolerite and Epidiorite dykes.

(IV) The Kurnool Series of sedimentaries which are divided into

- (1) Koilkuntla limestones (*Khoondair group*)
- (2) *Paneum group.*
- (3) Owk shales.
- (4) Narji limestones.

} *Jummulmudgoo group.*

- (5) *Banaganapalle group.*

The most important outcome of the survey of the area is the discovery and demarcation of a band of Dharwars extending, roughly diagonally, from the Tungabhadra

river near Rajapuram[1] in Raichur Taluq, right across the Do-ab to the Kistna river 6 miles north of Deodrug[2]. Besides this, other minor bands of Dharwars have also been demarcated. These formations afford an interesting study in phases of regional metamorphism.

I *Dharwars*.

The Dharwar bands demarcated in the area under report have escaped the notice of the earlier workers in the area. This band has been named by the Geological Survey Department as the Raichur Band for obvious reasons. In the earlier report, (Journal, Vol. II, pt. i) the Deodrug inlier was described as an outlying patch of Dharwars. This season's work has proved that this patch is really the north-western extremity of a band of Dharwars which runs across the country south-west to the Tungabhadra river, and beyond, into British territory. This main band of Dharwars and several minor bands have been mapped and these will be described in detail below.

RAICHUR BAND

This is by far the longest band of Dharwars located in the Raichur District. Taken together with the Deodrug patch, which is really the north-western extremity of the band, this band of schists runs diagonally from the Kistna river about 6 miles north of Deodrug, through Masarkal, Masjidpur,[3] Kalmali, Kallur, Naglapur,[4] Hanchinal[5] to Rajapuram on the north bank of the Tungabhadra, having a length of about 60 miles. From the Kistna river to Kalmali it occurs as a narrow spindle, the broadest portion being about 3 miles between Maladkal and Gabur. From Kalmali, the band bulges out west and N.E., the broadest portion from east to west being about 12 miles. Further S.E. the band gradually narrows again and reaches as far as the Tungabhadra south of Gundravali[6] (western

1. Rajapuram (C. 3 ; 3.7). 2. Deodrug (A1 1 ; 1.6). 3. Masjidpur (A. 1 ; 5.1). 4. Naglapur (B. 2 ; 4.1). 5. Hanchinal (B. 2 ; 5.1). 6. Gundravali (B. 3 ; 7.8).

boundary) and Rajapuram (eastern boundary) villages. It then passes out of the Hyderabad State into British territory where it has not been followed.

The western boundary of the band runs through or in proximity to the villages of Masarkal, Kakargal, Maladkal, Masjidpur, Kalmali, Nilagal, Hukreni,[1] Garaldinne,[2] Matmari,[3] Partipalli,[4] Turkandoddi,[5] Duganur,[6] Hanchinal, Gandhalu,[7] and Gundravali. The eastern boundary may be roughly followed along the villages of Masarkal, Shankeshwar,[8] Lakshmanpur,[9] Murharpur,[10] Ulapahad,[11] Eklaspur,[12] Askihal,[13] Muhammadapur,[14] Udamgal,[15] Yergara,[16] Gudawaram,[17] Godahal,[18] Gunjipalli,[19] Yedaknur,[20] Mirzapur,[21] Tottinenidoddi,[22] Kottapalli[23] and Rajapuram.

In this big band of Dharwars, approximately 225 sq. miles in area, though type chlorite, hornblende and diabase schists are frequently encountered, we meet with reconstituted varieties which obviously owe their structural and mineralogical characters, to intense metamorphism, presumably induced during the period of evolution of the Peninsular Crystalline Complex. The various types of schists are briefly described below.

Chlorite Schists.

Chlorite schists are observed in several well sections and nullah cuttings in this band of Dharwars. In the Shankeshwar-Ramdrug path, chlorite schists occur in several places with N.W.-S.E. strike and S.W. dip. Associated with these are hornblende schists. Between Lakshmanpur and Gabur chlorite schists are exposed. Along the path

1. Hukreni (A. 2 ; 6.5). 2. Garaldinne (B. 2 ; 1.3). 3. Matmari (B. 2 ; 2.2). 4. Partipalli (B. 2 ; 3.2). 5. Turkandoddi (B. 2 ; 3.1). 6. Duganur (B. 1 ; 4.9). 7. Gandhalu (B. 1 ; 6.9). 8. Shankeshwar (A. 1 ; 4.3) ; 9. Lakshmanpur (A. 1 ; 5.2). 10. Murharpur (A. 2 ; 8.9). 11. Ulapahad (A. 1 ; 9.2). 12. Eklaspur (B. 2 ; 3.8). 13. Askihal (B. 2 ; 3.8). 14 Muhammadapur (B. 2 ; 3.6). 15. Udamgal (B. 2; 4.5) 16. Yergara (B. 2 ; 6.3). 17. Gudawaram (B. 2 ; 5.3). 18. Godahal (B, 2 ; 5.2). 19. Gunjipalli (B. 2 ; 6.2). 20. Yedaknur (B. 2 ; 8.1). 21. Mirzapur (B. 1 ; 9.9). 22. Tottinenidoddi (C. 3 ; 2.9). 23. Kottapalli (C. 3 ; 2.8).

between Maladkal and Masjidpur in several places chlorite schists are met with. Typical exposures of chlorite schists are seen around Masjidpur. A light blue quartz vein cuts through the chlorite schist here. The body of the schist band between Murharpur and Kalmali consists of chlorite schists associated with hornblende and diabase schists at the margin. In the nullah between Kalmali and Nilagal the diabase schists are seen to alter into chlorite schists. Here, the schists strike E.N.E.-W.S.W. and dip S.S.E. Siddanbhaihuda,[1] Niluhalli,[2] Khanapur,[3] Udamgal and Yergera show hornblende schists passing into chloritised masses. At and around Husalhuda[4] are also chlorite schists occurring to the exclusion of the other types of schists. All these outcrops of chlorite schists generally strike from N. 30° W. to N. 45° W. with a south-westerly dip, the amount of dip varying from 50° to 80°. The above list of localities where chlorite or chloritised schists occur in the band is by no means exhaustive.

From a field study of the type chlorite schist—as seen in the Murharpur-Kalmali band and in the neighbourhood of Masjidpur and Husalhuda—it is observed that these constitute a narrow strip amidst the more resistant hornblende and diabase schists. Attention may be drawn to analogous relationship between the chlorite and hornblende schists around the ferruginous quartzites of the Tawargeri area.[2]

The type chlorite schists have to be distinguished from the chloritised hornblende and diabase schists. In the latter case the gradation in successive stage from such chloritised masses to the parent hornblende or diabase rock can be frequently made out in the field, whereas in the former, the boundary between the chlorite and the the hornblende schists is more or less sharp and well defined. In contradistinction to the soft, soapy feel of chlorite schists observed in the western part of the Do-ab, we see here that the chlorite schists have undergone a great deal of secondary induration due to subsequent metamorphic changes.

1. Siddanbhaihuda (B. 2; 1.7). 2. Niluhalli (B. 2; 2.6) 3. Khanapur (B. 2; 1.1). 4. Husalhuda (A. 2; 9.7).

2. Jour. Hyd. Geol. Surv. Vol. II pt. 1 pp 15-16.

Hornblende and Diabase Schists.

Hornblende and diabase schists are recognised in several places all along this band of Dharwar schists. Between Masarkal and Shankeshwar and along Shankeshwar-Ramdrug, and Shankeshwar-Maladkal paths, hornblende schists are exposed in several places. Diabase schists occur in association with these, specially on higher black cotton-soil areas. In the neighbourhood of the deserted village of Tippapur[1] hornblende schists are seen outcropping in association with diabase and siliceous schists. These have an average strike of N. 30° W. with a dip towards W.S.W., the amount of dip varying from 50° to 80°. Between the deserted village of Lakshmanpur and Gabur, hornblende and diabase schists occur side by side.

In the area a mile south of Sultanpur[2] to Kalmali hornblende schists frequently enclose softer chloritic members. In the neighbourhood of Venkatapur[3] and Gonhal,[4] type hornblende schists are seen side by side with siliceous schists. At both these places the schists are traversed by white and pale blue quartz veins. Further north, near Siddanbhaihuda, Muhammadapur and Malshettihalli,[5] hornblende schists outcrop in several places and these are frequently seen to alter into chloritised schists. Chloritised hornblende schists are also seen in the Garaldinne-Kurdi[6] path. Diabase schists occur with hornblende schists between Kallur and Dinni.[7]

East of the M.S.M. Railway line, type hornblende and chloritised schists are seen extensively developed at Khanapur, south of Udamgal, in the cart-track between Yergera and Gudawaram, and in several places between Yedaknur and Mirzapur.

The general strike direction of the hornblende and chloritised schists varies from N. 25° W. to N.W. with south-westerly dips which vary in amount from 50°-70°.

1. Tippapur (A. 1 ; 3.3). 2. Sultanpur (A. 1 ; 7.2). 3. Venkatapur (A. 2 ; 6.9). 4. Gonhal (B. 2 ; 1.9). 5. Malshettihalli (B. 2 ; 2.5). 6. Kurdi (A. 2 ; 8.2). 7. Dinni (B. 2 ; 1.4).

It may be noted in passing that the diabase and hornblende schists are so intimately associated that to separate the two groups in the field is rather difficult.

Granodioritic Rocks.

In this band of Dharwars, by far the most important and interesting rocks met with are the granodioritic schists. These rocks occur right through the whole band and are intimately associated with type chlorite and hornblende schists. In hand specimens, these rocks exhibit a great variation in texture and mineral constitution. Close examination in the field reveals that these granodioritic rocks in the schist band owe their existence to a complete or partial, structural, textural and mineralogical changes undergone by the original type schists as a result of regional metamorphism. Localities where such granodioritic rocks are typically developed are marked G.D. on the geological map No. 2.

No intrusive relationship of these granodioritic rocks to the type schists could be noted ; but on the other hand, an imperceptible gradation is traceable from type schists to the granodioritic phases. Apophyses and tongues of the granodiorites are non-existent, neither is there any schlierin development.

If the granodiorites are assumed to be intrusive into the type schists of the area, structural disturbance in the disposition of the original schists should be expected, but field observation brings out the fact, that both the type schists and the granodiorites show a similarity in strike and dip.

Phases of Weathering.

Megascopically, these granodiorites show gradations from fine-grained siliceous varieties to medium and coarse-grained types. In some of the fine-grained varieties, blue blebs of granular quartz are recognised. The medium and coarse-grained specimens reveal hornblende, augite, dirty white feldspar, epidote, magnetite and micas (specially at the contact zone) and occasional needles of apatite.

Rarely the granodioritic schists alter into chloritised types ; on lithological grounds, it often becomes difficult to distinguish a type chlorite schist from such a chloritised schist. Field evidence however, helps us to distinguish the original relation.

Almost universally, these reconstructed rocks are characterised by ribbed weathering and such weathered masses assume fantastic shapes. The intermediate and basic varieties of granodiorites also weather into ribbed and pitted outcrops (*Vide* Photos 1 and 2 Plate III).

It is not however usual to find the granodiorites weathering into chloritised schisted types. Also the siliceous schists weather sometimes into types which are conveniently given the field name of *schisted gneisses*. This nomenclature is by no means intended to convey affinity of the types to the members of the Crystalline complex or to the Champion gneissic series.

Siliceous Schists.

In the Deodrug patch of Dharwars, silicification of the schists is prominently observed, specially in the neighbourhood of Chik-Honkuni[1] and the deserted village of Saswikeri[2] in close association with hornblende schists. The schists are cut through by pegmatoid gneisses and silicification of the hornblende schists seems in great part to be due to assimilation of the acidic intrusives. In this band may be seen *par excellence* the structural relation of the type hornblende and the so-called siliceous schists, the latter being due to metamorphic effects induced into the original hornblende schists, presumably during the period of the granitoid gneissic activity.

Further south-east, between Masarkal, Maladkal, Masjidpur and Gabur, in close association with chlorite and hornblende schists, fine-grained dark grey siliceous schists are frequently met with, sharing the same structural features as of the type schists.

1. Chik Honkuni (A_1. 1 ; 3.6). 2. Saswikeri (A_1. 1 ; 2.6).

Several outcrops of siliceous schists in the nullahs in proximity to Venkatapur, Kalmali, Fatyapur[1] and Gonhal are fine-grained siliceous types, frequently grading into hornblende and chlorite schists. In close association with these are seen either quartz veins or aplites. The Kalmali hills consist almost exclusively of fine-grained dark schists in which blue blebs of quartz lie scattered as pyroclastic fragments.

Between Kalmali and Nilagal, the dark fine-grained siliceous types grade into medium-grained granodioritic phases. In the Kalmali group of hills, in the highly silicified fine-grained types, blue blebs of quartz are seen in granular disposition, studded in the body of the massive rock. Such an occurrence of blue blebs is by no means universal in other localities. It seems reasonable to assume from field observation that the silicification of the Kalmali hill must have been due to assimilation of quartz veins—probably blue quartz veins, as a pyroclastic material during the period of regional metamorphism to which the area seems to have been subjected.

The siliceous fine-grained types in the granodioritic phase of the schist band are very well developed south of Raichur-Uttanur road in great profusion. There too, their association with the type hornblende and chlorite schists is evidenced in several places along the footpaths and cart-tracks leading from Kallur to Nilagal, Kalmali, Siddanbhaihuda, Muhammadapur, Niluhalli, Malshettihalli, Dinni, Garldinni and Kurdi.

East of the M. & S. M. Railway line, similar dark fine-grained siliceous schists have been observed in several places in intimate association with type hornblende and chloritised schists. They form prominent outcrops along the margin of the boundary of the schists and Peninsular gneisses. Yergera, Partipalli, Gandhalu, Sindhanuru[2] and Turkandoddi may be instanced as type localities of these siliceous forms of the reconstituted Dharwars to the

1. Fatyapur (B. 2 ; 2.9). 2. Sindhanuru (C. 3 ; 2.8).

east of the Railway line. Crude marks of schistosity often indicate their original trend.

Medium to Coarse Grained Granodioritic Schists.

The distinction between the dark, fine-grained *siliceous schists* and the medium to coarse-grained granodiorite seems more or less artificial, the main difference between the two being one of texture. Mineralogical gradations in the fine-grained varieties have their counterpart in the coarser granodioritic schists.

There is one interesting field relation which may be mentioned here with relevance. It is more frequently observed between Shankeshwar and Muhammadapur that closely associated with the siliceous forms of the granodiorites, are seen pegmatites, or quartz veins and aplites. Regionally considered, the outcrops along the eastern boundary of the schist band to the west of the Railway line display this feature prominently. East of the Railway line however, the contact of the pegmatites with granodiorites gives rise to medium-coarse grained texture in granodiorites.

On the western side of the band, specially from Garldinni to Nilagal, the contact zone of the Dharwar schists and crystalline gneisses shows a very poor development of pegmatite or quartz veins. It is seen that the granodioritic phases do not show here much silica as do the fine-grained siliceous types, though interstitial quartz in minor quantities is commonly detectable. The granodiorites here are difinitely medium to coarse-grained in contrast to the massive fine-grained types seen in proximity to pegmatite and quartz veins along the eastern boundary, to the west of the Railway line.

Nilagal hill (*Vide* Photo 6, Plate IV.) and several outcrops to about a mile east of Nilagal consist of medium-grained granodioritic schists. Along the western margin of the boundary of this band of Dharwars, between Nilagal and Garldinni, the same type preponderates, though occasionally may be seen gradations of these into the dark, fine-grained siliceous schists. At the junction

of the Dharwars and the Peninsular Crystalline Complex the assimilation of the granitoid gneissic material is widespread and hybrid types have frequently a wide range of distribution along such contact. The demarcation of the schist boundary in such instances cannot be rigorous and preponderance of the constituent minerals becomes the main criterion for fixing the actual line. This ambiguity in defining the boundary is not, however, a universal feature, since, more frequently than not, the actual contacts of the schists and crystalline gneisses are observed in several places along the junctions.

Medium-grained granodioritic schists may be seen outcropping along the path or cart track from Kallur to Nilagal, Uttanur, Shakapur,[1] Hukreni and Kurdi. Type specimens of these rocks will be described in the section under petrology. As already emphasised, the absence of pegmatites and quartz veins in the vicinity of these medium-grained types, is a feature worthy of note. Passing reference may be made here to the assimilation of pink or red feldspars at the contact zone in schists and granodiorites from the pink pegmatites and red syenites. This will be further discussed in the section dealing with the Peninsular Crystalline Complex. The *lit-par-lit* injections of the pink pegmatites and red syenites along the junction of schists and gneisses will be likewise referred to in a later section.

The Kallur hills afford a remarkable example of the alteration undergone by the original schist band due to dynamic forces that have come into play in this area. Medium to coarse-grained granodiorite types that now and then grade down to fine-grained siliceous types are seen both in the hills and at their foot. North-east of Kallur the association of the type hornblende and chlorite schists with granodioritic types is met with in several places.

Mention may be made here of another interesting field character prominently seen around Kallur. Amidst the dark medium-grained granodiorites here, are seen small

1. Shakapur (A. 2 ; 4.6).

islands of lighter coloured types of similar texture, which very much resemble grey gneisses of the Peninsular Complex. These also weather into ribbed types. Feldspar is developed in good quantity and next in abundance are ferro-magnesian minerals, quartz being subordinate. The minerals are in granulitic and porphyritic forms. On account of the small size of these islands it has not been possible to represent them on the field map. Such instances are also noted in Partipalli east of the Railway line. It is not possible to say with any amount of certainty as to whether this is due to the recrystallisation of the acid members of the Dharwars with assimilation of a part of the basic schists, or whether these are to be ascribed to the squeezing in of the granitic magma and assimilation with the basic schists during the period of the invasion of the Peninsular Crystalline Complex. Under the microscope these lighter coloured granulitic rocks display pronounced schistosity.

East of the Railway line, these medium to coarse-grained granodioritic types in many localities occur in lenticular shredded patches, sometimes dyke-like, often as flat domes and in low ridges, bare of vegetation and almost always in intimate association with type hornblende and chlorite schists. To the north of Mirdoddi[1] as well as to the west to the Nandani[2] Kondapur[3] track, in the nullah to the north of Patapalem,[4] between Partipalli and Turkandoddi and in Kottapalem[5] hills, the coarse-grained granodioritic types are met with. Mention may be made here of the sheets of pale pink and white pegmatites which overlap and mantle the granodioritic rocks between Partipalli and Turkandoddi, (*Vide* photos 3 & 5 Plate III & IV). Denudation has resulted in exposing in a few places the underlying granodiorites. A pale pinkish blue look characterises the lighter coloured types in brilliant sunlight. Here too, gradations exist from the dark coloured medium-grained rock to more acidic forms similar in composition

1. Mirdoddi (C.2 ; 4.2). 2. Nandani (C.2 ; 1.8). 3. Kondapur (C.2 ; 3.9). 4. Patapalem (C.1 ; 5.1). 5. Kottapalem (C.1 ; 6.1).

to the normal grey gneisses of the Peninsular Crystalline Complex. Field characters, however, bring out their genetic relation to the reconstructed granodioritic family and seem to suggest that these are the acid representatives of this group.

Schisted Gneisses. This is a loose field name which has been indiscriminately applied to the members of the Dharwars which on weathering give rise to lighter coloured outcrops showing definite schistosity. This lighter colour seems to be due to the wide-spread kaolinisation of the feldspar in the schists. Thus, these *schisted gneisses* are commonly observed in association with siliceous schists in the band. At first sight these are deceptive and are likely to be mistaken for members of the Peninsular Gneissic group but closer field examination reveals their real identity. These schisted gneisses have the same strike and dip as that of the type schists and reconstructed members, i.e., from N 20° W to N.W. and a south-westerly dip. Their gradation to unaltered siliceous and medium-grained granodioritic phases is a sufficient proof as to their true genesis.

Sometimes we meet in the other minor bands of Dharwars some members of the *Champion Gneissic Series* which are now included in the Dharwar group. They seem to have generally lost their identity and merged into the basic schists, thus accounting for a great deal of silicification now observed in the reconstituted granodioritic phases.

MINOR BANDS OF SCHISTS.

In addition to the main band of Dharwar series just described, a large number of shredded patches are encountered in the area varying in size from outcrops of a few yards in length to islands of respectable dimensions amidst the Peninsular gneisses.

For purposes of convenience these may be grouped together and described. North of the Sirvar-Raichur road in proximity to the main Raichur band of Dharwars are

seen a number of patches to which passing reference may be made here.

Amrapur patch.

Amrapur[1] patch has already been described in Vol. II. pt. i of the Journal.

Timmapur patch.

The Timmapur[2] patch of schists is surrounded by the villages of Gabur, Sultanpur, Hanumapur[3] and Timmapur. In this patch, the hornblende and diabase schists as well as siliceous varieties are seen to outcrop. The siliceous fine-grained schists are prominently developed in proximity to the pegmatites. Tourmaline-bearing pegmatites are fairly common which cut this band. In this patch of schists many structural peculiarities are observed east of Gabur; the strike varies from N 15° W to N 35° W and the dip is in some places north-easterly, and in others south-south-westerly. In the body of the schist patch, the schists strike N.E.-S.W. and dip N.W. Near Timmapur the schists strike N.W.-S.E. and dip S.W.

Hospet-Ulapahad patch.

Hospet[4] Ulapahad patch occurs to the S.E. of Gabur-Hanumapur path. The rock types here are mostly siliceous and weather frequently into what has been loosely called *schisted gneisses*. The development of mica at the contact of the gneissic representatives is a common feature. Very often along the margin of the patch, chilled contact rocks of gneissic and schisted types are met with. The pink pegmatites and red syenites are seen prominently developed at the boundary. A salt work is seen E.N.E. of the boundary. The dolerite dyke, which cuts through both the patches described above, is clearly post-gneissic in age.

Ganekal patch.

A kidney-shaped patch running through Ganekal is of some importance in that we get here interesting structural features.

East of Ganekal the reconstructed schists are in contact with grey gneisses. Here, we get types which show coarse granulitic structures in the body of the schists.

1. Amrapur (A.1; 4.3). 2. Timmapur (A. 1; 8.4). 3. Hanumapur (A.1; 9.3). 4. Hospet (B.1; 2.2).

To the west of Ganekal hill, pegmatites—specially pink pegmatites—outcrop along the junction. The representatives of Dharwars in proximity to the pegmatites are the fine-grained siliceous types. Even in a small patch, we see here the various aspects of the alterations undergone by the original schist band, due to variations in the characters of the members of the crystalline complex at the zone of contact.

Valkamdinne patch.

West of the Railway line, omitting a number of very minor outcrops of Dharwar schists, mention may be made of the Valkamdinne[1] band of schists which has roughly a length of 9 miles and an average width of a mile. Its north-western part is masked north of Bayalmarchaid[2] by the black cotton-soil cover but to the S.E. the band runs with a recognisable boundary till it cuts the Tungabhadra river between the Railway bridge and south of Bichala.[3] This band typically consists of the diabase, hornblende, and chlorite schists with a north-west south-easterly strike and south-westerly dip. Pegmatites not only girdle the band at margins but cut through it in parallel disposition.

East of the Railway line a number of minor patches are seen, the more important of which are mentioned here.

Yegnur[5] and Ibrahimdoddi patches.

North of Yermaras[4] some patches of Dharwar schists have been mapped and they are mostly the type schists. The patch west of Ibrahimdoddi[6] consists mostly of the reconstructed types.

North and South Vedvatti patch.

Shredded outcrops of schists a mile and a half N.E. of Raichur, on the cart-track to Chandrabanda[7] consist of type Dharwar schists. The few outcrops of schists south of Vedvatti[8] are similar in character to the above group of schists.

1. Valkamdinne (A.3 ; 9.9). 2. Bayalmarchaid (A.2 ; 6.2); 3. Bichala (B.3 ; 3.8). 4. Yermaras (B.1 ; 4.1). 5. Yegnur (B.1 ; 5.2). 6. Ibrahimdoddi (B.1 ; 7.3). 7. Chandrabanda (B.2 ; 8.9). 8. Vedvatti (B.2 ; 7.8).

Minor patches between Macherla[2] and Yaklaspur[3].

Some small patches of Dharwar schists are noted along the cart-track beyond Balgeri[1] on the Macharla track and on the Macharla-Mirdoddi tracks. The schists in these areas are only shredded remnants in association with reconstituted gneissose rocks at the margin. The boundary of these has been only roughly delineated.

Idguanpalli patch.

A comparatively wide exposure of hornblende schists may be noted in the villages of Anthampalli,[4] and Idguanpalli,[5] reaching as far as Utnur[6] with a strike disposition N. 30°W. The boundary of this schist patch is not easily located on account of the soil cover and the pegmatoid gneisses that overlap the schists. The boundary of the schists in many places is a surmise.

Shredded patches in Gadwal area

The reconstructed types of Dharwar rocks occur in many localities in the Gadwal[7] Samasthan in shredded disposition. In fact, their large development is met with in the flanking margin of the main Gadwal band of schists, but their occurrence is so irregular that mapping of their boundary could not be attempted.

GADWAL BAND OF SCHISTS.

This band or inlier of Dharwars extends from the Kistna river in a S.S.E. direction and in the area under review is second in order of magnitude comprising about 47 sq. miles.

The band was traced from the south of the Kistna river (probably it continues further north also) passing west of Gadwal and reaching up to Vallur.[8] This is separated from another band—the Vemla[9] band, to S.E. by a bed of transition rocks—*autoclastic conglomerates*. Though the boundary of the band of schists had not been demarcated

1. Balgeri (C.2 ; 2.3). 2. Macharla (C.2 ; 2.4). 3. Yaklaspur (C.2 ; 6.2). 4. Anthampalli (C.2 ; 4.1.) 5. Idguanpalli (C.2 ; 4.1). 6. Utnur (C.2; 5.1). 7. Gadwal (D.2 ; 2.9). 8. Vallur (D.2 ; 6.1). 9. Vemla (D.2 ; 6.3).

by Bruce Foote, the existence of this band seems to have been known to earlier workers in the area, as supposed old Gold Workings are reported by T. Knight in his prospecting reports.

From the Kistna river, the band runs southwards into rugged, more or less continuous hummocky outcrops for a distance of 6 miles. Further southwards, the eastern half of the band continues in like manner a little beyond Kondapalli[1] village and then gradually is lost under the black soil cover. The western boundary like the Vemla inlier to the S.E. is almost completely covered by a thick layer of black cotton-soil.

The Gadwal and Vemla bands consist of the type and *reconstituted* schists. The basic as well as the acidic members of the Dharwars are recognised in this band and the petrographic relations already enumerated hold good here as well.

Autoclastic conglomerates similar to those at Palkanmardi, fully described in Vol. II pt. i, have been found to occupy the country between the Gadwal and the Vemla inliers. The numerous tongues and apophyses of the pegmatoid gneisses are seen to have penetrated the pre-existing basic rocks and these were subsequently broken and fragmented by the shearing stress and heat evolved in the later stages.

TOURMALINE BEARING PEGMATITES.

In the area under report, the relationship of the pegmatites and quartz veins to the Dharwar series on the one hand and to the Peninsular Crystalline Complex on the other, presents some interesting features which may here be briefly referred to.

The pegmatites occurring in the area may be classed under three groups.

(1) Tourmaline bearing white pegmatites, sometimes showing schisted disposition.

(2) Binary pegmatites belonging to grey series.

(3) Binary pegmatites belonging to pink series.

1. Kondapalli (D.2 ; 2.6).

(2) and (3) will be dealt with in the section on Crystalline Complex.

The tourmaline-bearing pegmatites have been observed in the area to occur only in the Dharwar band. They fringe the margins and often run through the schists in all directions. Several veinlets of tourmaline-bearing pegmatites cut in parallel disposition amidst the schists between Maladkal and Gabur. In an unlined well at the intersection of Gabur-Masjidpur track and Maladkal-Sultanpur path, a pegmatite vein is seen to cut through chloritised schists.

Similar tourmaline-bearing pegmatites are noted in the body of the Dharwar bands between Timmapur and Sultanpur, south of Jagarkal[1] and west of Muhammadapur, Malshettihalli, Dinni, *etc.*

On account of their exclusive association with the Dharwar rocks in the area, these may be regarded as pre-Crystalline Complex in age.

BLUE QUARTZ VEINS.

Passing reference may be made here to the quartz veins which cut through the Dharwar bands. In size and extent these are not of any great magnitude. They are mostly blue to light grey in colour and are observed traversing the type schists for short distances.

Both light blue and slaty blue quartzites are seen scattered in the made-ground south-south-east of Shankeshwar. In a small tank west of Masjidpur, light blue quartz veins cut through the chlorite schists.

Some outcrops of light blue veins of quartz along the margins of the chlorite schist band between Sultanpur and Kalmali grade into whitish varieties.

In the Kalmali hills, it is frequently noted that the fine-grained schists have become highly siliceous and blue blebs of quartz are scattered profusely in the massive schists. This fact seems to strongly suggest that during

1. Jagarkal (B.1; 2.3).

the re-fusion and reconstitution of the original Dharwar schists, the associated blue quartz veins have been partially assimilated, accounting for the great silicification exhibited here by the bands. The pyroclastic materials seem to have been only partially assimilated as evidenced by the fact of the presence of unassimilated blebs of blue quartz scattered in the ground mass. This suggestion is further supported by the occurrence, in proximity, of indurated chlorite schists.

In association with the type hornblende schists near Muhammadapur, Niluhalli, Malshettihalli, Udamgal and Gudawaram, blue quartz veins are frequently met with.

In the Valkamdinne inlier both light blue and grey quartz veins run in the body of the Dharwar schists, frequently showing ferruginous staining.

In the Gadwal band of Dharwars light blue quartz veins are noted as isolated outcrops from the south of Kistna river to Gadwal town.

It is interesting to note that the blue quartz veins are almost invariably associated with the type Dharwar schists and rarely, if ever, with the reconstituted types.

Samples from all the outcropping blue and light blue quartz veins were crushed and panned but the concentrates gave no indication of gold.

II. *Peninsular Crystalline Complex.*

In Vol. II, pt. i of the Journal, Hyderabad Geological Survey, the relationship of the Peninsular Crystalline Complex to the Dharwar series and the field and microscopic characters of this group have been discussed at length. Here, attention will be mainly confined to the structural relationship of the grey and pink members of the Peninsular Complex to the Dharwar bands in the area under review.

The grey series form the country rock in the area.

Grey Series.

The prominent hills of Deodrug, Masarkal, Kakargal, Gabur, Sirvar, Uttanur, Nirmanvi, Gorkal, Manvi and Raichur consist almost entirely of the grey gneisses. Regionally pictured, the contact zone

between the schists and the gneisses is usually characterised by the presence of the pink series of gneisses and the grey series occupy the country away from these pink gneisses. The gradations between the grey and the pink gneisses are imperceptible and direct contact between the grey and pink gneisses is rare.

Though as a rule, the junction of the Dharwars and the Peninsular Complex is flanked by pink gneissic series, it is also occasionally noted that the grey series form bays and islands in the body of the Dharwar rocks. An outstanding instance of the above is observed around Partipalli, Matmari and Turkandoddi. In contrast to the apophyses, tongues and *lit-par-lit* injections which characterise the junction of the Dharwar rocks and the pink gneisses, it is seen that the grey series hardly show any marked contact effects with the Dharwars. At such contact there is however clear evidence of assimilation of the hornblende of the schists by the grey gneisses, when it sometimes becomes very difficult to distinguish from the hand specimen between a grey gneiss and the reconstituted lighter coloured granodioritic rock. Grey spotted gneiss and hornblende gneiss characterise the junction but further away from the junction, normal grey gneisses are observed where the place of hornblende is taken by biotite mica. Very frequently, the grey gneisses are binary with practically no ferromagnesian accessories.

White Pegmatites & Aplites.

White binary pegmatites and aplites cut through the grey gneisses in several localities. Instances of these are seen in the Manvi and Gorkal hills and in proximity to these hills. They are seen in greater prominence at the contact of the Dharwar schists and the grey gneisses. A number of binary pegmatites cut through the body of Valkamdinne patch of Dharwars. Their greatest development is however noted in the Matmari-Partipalli-Turkandoddi area. Between Matmari village and Matmari Railway Station they are developed in profusion as parallel veins cutting through

both the gneisses and schists. Between Partipalli and Turkandoddi they mantle the Dharwar rocks, very often only the well sections and other cuttings exposing the members of the schist series, and the higher elevations being covered by the white pegmatitic sheets. Sometimes the pegmatites send zigzag tongues into the granodiorites.

This feature introduces perplexing problems while demarcating the schist boundary, but very careful examination reveals the real nature of the country.

In the Timmapur patch of Dharwars, white aplites in contact with the siliceous schists show some druses which are now occupied by quartz. A great deal of staining by copper salts lends a pleasing hue to the rock.

Pink Series.

As has been mentioned, the pink series are usually seen to occupy the country between the Dharwar belts and the grey gneisses. They grade insensibly into grey gneiss but frequently show intrusive effects at their junction with the Dharwar rocks. As regards their distribution, regionally viewed, the pink members are more extensive to the west of the Raichur band, whereas along the eastern boundary they constitute a narrow belt and grade rapidly into the grey series. Towards the south, the pink gneisses and pink porphyries are seen occupying the Tungabhadra basin.

Pink Pegmatites.

Pink pegmatites and aplites are seen to cut through the gneisses and schists along their junction zone. The pink pegmatites and aplites reveal extensive and intensive intrusive relationship into the Dharwar rocks of the area for appreciable distances.

Pink pegmatites are seen on either side of the junction of schists and gneisses between Shankeshwar and Tippapur, on the borders of the schist boundary between Sultanpur and Kalmali, around Nilagal, between Jagarkal and Naglapur—especially in the nullah east of Naglapur—west

of Chiksugur[1] village, between Uttanur and Maladkal, and between Muhammadapur and Matmari.

These pegmatites are not much in prominence near the junction of schists and crystalline complex on the western boundary between Nilagal and Garldinne, but they are well developed in the zone of pink gneisses further west, away from the boundary. Thus, between Uttanur and Hardigudda, in the gneissic country, a large number of them are seen to cut through the pink gneisses. Along the eastern margin of the Raichur band of Dharwars, these often occur in *lit-par-lit* injections in association with red syenites, in the body of Dharwars, partaking of the structural features in common with the Dharwar rocks. Pink pegmatites are likewise found to cut the body of the Valkamdinne and other minor patches of schists in several places. Their presence is often taken as indicating proximity to the junction.

Red Syenites.

Red syenites are seen best developed along the junction of the schists and the Peninsular Complex in several places. They send apophyses and tongues into the schist band and like the pink pegmatites, show *lit-par-lit* relation in the body of the schist band near the junction. Red syenites are prominently recognisable in the neighbourhood of Masjidpur, Ganekal, Venkatapur, Nilagal, Naglapur, Chicksugur, Mirapur and Hukreni at the junction of the schists and Peninsular Complex.

Between Niluhalli and Siddanbhaihuda, on the path from Muhammadapur to Niluhalli, on the Kurdi-Niluhalli path and 9 miles south of Kurdi in the Valkamdinne patch of schists, red syenites are seen to cut through the Dharwar band and occur as caught up fragments or scattered patches in the Dharwar formations. They show intrusive relationship into the grey as well as the pink gneisses and are thus younger than both.

Besides the veinlets of green epidote (pistacite) which cut through the red syenites in many places, secondary

1. Chiksugur (B.1; 4.3).

alteration of the feldspars of the syenites to epidote is also universally observed in the area.

White Quartz Reefs and Veins.

A number of quartz reefs and veins have been traced in the gneissic country. Their position and extent are indicated on the map. Among the more important, the reefs in proximity to Yeramsar, Mallapur,[1] Nirmanvi, Bayalmarchaid, Yedaknur and Induvasi[2] may be mentioned as good examples. They all show frequently ferruginous staining and in the quartz reefs near Yeramsar, greater concentration of iron in the quartz reef gives rise to small patches of hæmatite. Brecciation is frequently observed in the quartz constituting the reefs. The quartz reefs are highly jointed and often present a bedded aspect. It is possible to get good quantity of milk white quartz from most of these reefs.

When the quartz veins are seen to be traversed by later dykes, the latter are usually noticed to be silicified. In such cases some of the pieces of vein quartz are also engulfed in the margin of the dykes.

III. *Dykes.*

A large number of dykes have been traced in the area under report. They are mostly doleritic in composition but instances are frequent where they have also been altered to epidiorites. A number of dykes between Gududinne[3] and Manvi run roughly from W.N.W. to E.S.E. and continue across the Tungabhadra into the British Territory. Some prominent members of this dyke system show xenolithic inclusions of gneisses and vein quartz from about 2 miles south of Kurdi to a mile south of Aruvalli,[4] (*Vide* photo 7 Plate IV). Another dyke which runs in a north-westerly trend for about 8 miles from Matmari shows porphyritic crystals of light green feldspar in a medium-grained ground mass with a typical *pepper and salt* structure.

1. Mallapur (B.1 ; 2.3). 2. Induvasi (C.2 ; 1.2). 3. Gududinne A.2 ; 1.3). 4. Aruvalli (B.2 ; 1.2).

Brief mention may be made of a chilled dyke which varies in width from 1 foot to 3 feet cutting through the Manvi hill. This chilled dyke shows frequent pitting all along its course and local legend connects it to Puranic story of Parikshit Raja,* (*Vide* photo 4 Plate III). A number of dykes have been traced south of the Kistna in the Deodrug and Raichur Taluqs and in Gadwal Samasthan. Their general trend is mostly east to west though a few run with a north-south trend.

All the dykes traced in the area are defintely seen to be post-Crystalline Complex in age, but stratigraphic evidence is lacking to define their upper limit.

IV. *The Kurnool Series of Sedimentaries*

These sedimentary rocks cover the whole area of the Alampur[1] Taluq, occupying the extreme south-eastern corner of the Raichur Do-ab, being bounded by the Kistna and the Tungabhadra rivers and limited to the west by the longitude 77°-55′-27″, comprising an area of about 147 square miles.

The area forms a small plateau, with a radiating drainage into the Kistna and Tungabhadra rivers.

ROCKS OF THE SERIES

The classification adopted by King† has been followed all through. His description of the rocks of the various groups has been found to agree in general, except for some local variations. A few local deviations in the boundaries of the series and the sub-groups have only been noted. So to avoid repetition only the characteristic local features are here touched upon.

Koilkuntla Limestones. (Khoondair group).

The Koilkuntla limestones which are of sub-earthy compact varieties, show clear bedding and split into flags. They range in colour from grey, dark grey to black, and occupy a small area, within which the villages of

*Mem. Geol. Sur. Ind. Vol. XII pp. 63-64.

1. Alampur (E.3; 5.5).

†See Mem. Geol. Sur. India. Vol. VIII.

Koneru,[1] Bukkapuram,[2] Emampur,[3] Kasipur[4] and Alampur are situated.

Paneum Group.

The Paneum quartzites which are found as distinct members in the type area, are wanting in this area under report, but vestiges of these rocks are noticed in some localities as intercalated bands associated with the Owk shales.

These intercalated quartzites are dark-brown to reddish-brown being stained by oxides of iron. They are fine-grained and compact sometimes grading into a sort of vitrified sandstone. Two sets of vertical cleavages along north-south and east-west directions permit the rocks to be split up into more or less square blocks, like the ramparts of a fort.

To the south of Sultanpur, along the southern bank of the Tungabhadra canal, there is a small area mainly composed of quartzites and associated conglomerates, the stratigraphical relation of which is not quite clear. At one place they are seen to be resting directly on the gneisse ; but just on the right bank of the river there is a meagre section suggesting an overlap of Narjee limestones. As the sequence is not clear, these beds have been indicated as Paneum quartzites as classified by King. (*Vide* map of Alampur Taluq, Plate II.).

Owk Shales.

These shales are found to crop out all round the edge of the Koilkuntla limestones, being characterised by their non-calcareous nature. From top downwards, they grade from buff to purple mottled shales. They are fine-grained and well laminated, the laminæ being particularly well seen in the buff varieties. The white and purple mottled shales are very compact and look like chert or biscuit-ware.

1. Koneru (E.3 ; 5.7). 2. Bukkapuram (E.3 ; 5.7). 3. Emampur (E. 3 ; 4.6). 4. Kasipur (E 3 ; 4.5).

These shales show considerable crushing effects and comparatively greater and gentler foldings than the limestones above and below them.

This group also shows a remarkable thinning and thickening in various parts of the field, and it is this feature combined with the differential sub-aerial denudation that has caused these rocks to outcrop at different horizons and to extend to different limits on the surface.

The thickness of these beds together with the intercalated quartzites is about a hundred feet.

The villages of Basavapuram,[1] Undevelli,[2] Amidalapadu,[3] Kanchupadu,[4] Takkasela,[5] Seripalli,[6] Yapaldevipadu,[7] Kyaturu[8] and Bhimavaram,[9] are all situated on the Owk Shales.

Narjee Limestones.

Beneath the shales mentioned above comes a set of limestones which are very compact, sub-crystalline, and extremely fine-grained. The colour is usually dark blue or black, but in other parts of the field they range from fawn to purple. The typical dark blue or black beds are extensively developed round the villages of Maramangal[10] and Paragtur.[11] The fawn coloured varieties found near the village of Kalugotla,[12] are more compact, fine-grained and very splintery breaking off with edges as sharp as knife-blades.

The villages, of Maramangal, Paragtur, Manyapadu,[13] Amaravayi,[14] Chinnapotulapadu,[15] Kalugotla, Puluru,[16] Jallapur,[17] Uppalapadu,[18] Chagatur[19] and Kundavelli[20] are all situated on the Narjee limestones.

1. Basavapuram (E.3 ; 3.5). 2. Undevelli (E.3 ; 2.7). 3. Amidalapadu (E.3 ; 2.8). 4. Kanchupadu (E.3 ; 2.8). 5. Takkasela (E.3 ; 2.9). 6. Seripalli (E.3 ; 3.9). 7. Yapaldevipadu (E.3 ; 5.9). 8. Kyaturu (E.3 ; 4.9). 9. Bhimavaram (E.3 ; 5.8). 10. Maramangal (E.2 ; 2.3). 11. Paragtur (E.2 ; 3.1). 12. Kolugotla (D.3 ; 9.6). 13. Manyapadu (D.3 ; 7.8). 14. Amaravayi (D.3 ; 7.8). 15. Chinna Potulapadu (D.3 ; 9.7). 16. Puluru (D.3 ; 9.5). 17. Jallapur (D.2 ; 9.1). 18. Uppalapadu (E.3 ; 8.7). 19. Chagaturu (E.3 ; 9.7). 20. Kudavelli (E.3 ; 9.7).

A small outlier of Narjee limestones lies to the north-north-east of Koludinne[1] village. Due to the soil cover the extent of this outlier could not be correctly demarcated. In the quarries and along the edges the beds show a converging dip.

Banaganapalle Group.

To the north-west of Uppalapadu village, below the Narjee limestones on the left bank of the Tungabhadra a set of thin beds 10 to 15 feet thick are seen capping the uneven gneissic ridges. They are composed of grits, pebble beds and conglomerates. The pebbles consist of quartzites, a few cherts, quartz, and very rarely gneissic fragments.

These beds are economically important being diamond bearing.

General lie of the beds.

Most of the beds lie horizontally, but at the surface they all show gentle foldings which gradually disappear with depth. The Banaganapalle beds show gentle dips, and are the lowermost beds which are lying uncomformably on the uneven surface of the older gneissic rocks.

Intercalated beds at the base of Jammalmudgoo beds.

Near the villages of Jallapur, Kalugotla, Borevelli,[2] Chinnapadu,[3] and Chinna Potulapadu, the base of Jummalmudgoo rocks which form the shore beds, grades down to jaspar beds, associated with sandstones.

The shore beds and the peculiar feature noticed above the confluence of the south Chandur[4] nullah with the Kistna river are detailed by Bruce Foote.*

Petrology

In the previous section the characters and field relation of the various rocks met with in the area have been discussed in general.

1. Koludinne (D.3 ; 5.9). 2. Borevelli (D.2 ; 8.1). 3. Chinnapadu (D.3 ; 8.8). 4. Chandur (E.2 ; 1.3).

*Memoirs. Geol. Surv. Ind. Vol. VIII p. 79.

(9) Epidote hornblende rock.
(10) Granulitic schists.

(1) *Coarse-grained granodiorite.*

Loc :—Half a mile east of Gandhalu,[1] Raichur Taluq.

In the hand specimen, it is a coarse-grained rock with a granitoid structure. Light blue vitreous quartz, glassy and white feldspars, hornblende and biotite can be recognised with the naked eye.

Under the microscope, the section reveals a granitoid structure with a medium to coarse-grained texture. It essentially consists of clear colourless grains of quartz which do not show much crushing. Some of the quartz grains exhibit undulose extinction. Feldspars mostly orthoclastic, partly kaolinised occur with subordinate quantity of microcline with its characteristic cross-hatching structure. The periphery of the orthoclastic feldspars is found to be often cleared of its decomposed products. Acid plagioclases are present with polysynthetic twining ; oligoclase sometimes shows development of secondary albite Hornblende with characteristic bluish-green colour and green to yellowish-green and blue-green pleochroism is present much broken and shredded. Some plates of hornblende exhibit pœciloblastic structure. (*Vide* micro-photo 16. Plate IX) Biotite also occurs in abundance. Some of the biotites show clear evidence of their being derived from hornblende with the separation of iron ore and silica. (*Vide* micro-photo 17 Plate IX). This feature is well marked in this section. A few flakes of biotite show pleochroic halos, while some others are baked. Apatite is abundant occurring both as rounded grains and prisms. Magnetite is also present and these are found crowded round about biotite from which they are mainly derived as a leached product. Stray flakes of glaucophane are also noted. (*Vide* micro-photo 1. Plate VII).

1. Gandhalu (B. 1 ; 6.9).

A number of micro-sections of the rocks have been studied and the following types have been chosen for detailed description, as they represent a series of rock types differing from those described in Vol. I, pt. i and Vol. II, pt. i of the Journal dealing with the western half of the Do-ab. In the present report some characteristic metamorphic structures have been described. A comparative study of some of the types with the *pseudo and quasi charnockites* described by the Mysore Geologists has also been made.

From an examination of the field collections in the area now under report, it is found that the Dharwar series are not only represented by the type schist members but also by an interesting series of rocks of granodioritic phase which characterise a major portion of the Dharwar bands. These granodioritic rocks range from coarse, through medium, to fine-grained varieties and sometimes also develop porphyritic types. These rocks also pass from acidic through intermediate to basic types. Ultra-basic and ultra-acidic varieties, however, have not been recognised.

It appears that these rocks have been produced by a series of metamorphic effects upon the type Dharwars and their acidic representatives, and that the types have resulted partly by assimilation and mostly by reconstitution. We have thus a series of rocks showing gradual mineralogical changes which can be easily followed under the microscope.

The following main types of rocks deserve special mention :—

GRANODIORITIC ROCK TYPES.

(1) Coarse-grained type.
(2) Medium-grained type.
(3) Fine-grained type.
(4) Porphyritic type.
(5) Acidic variety.
(6) Intermediate variety.
(7) Basic variety.
(8) Epidotised rock.

(2) *Medium-grained granodiorite.*

Loc:—Half a mile west of Tottinenidoddi,[1] Raichur Taluq.

It is a dark grey medium-grained rock in which the component minerals can be made out with the naked eye. Schistosity is not in evidence in the hand specimen. There are islands of basic segregation consisting mostly of hornblende.

The rock section presents a holocrystalline, pœciloblastic structure, the ferro-magnesium minerals showing a tendency towards crude parallelism. The quartz is more or less crushed and is often in pœciloblastic relation to feldspars. The feldspars are mostly kaolinised and occur in broad plates showing relic structure with peripheral granulation. Kaolinisation seems to have taken place sometimes along cleavage lines and sometimes in irregular patches. Orthoclase, microcline along with acid plagioclases form the bulk of feldspars. In areas where crushing is more intense, a coarse mosaic of quartz and feldspar is seen. Secondary albite in rods and needles is a common inclusion, as incipient crystals in the plagioclase feldspars.

The ferro-magnesian minerals mostly consist of blue green hornblende, which occurs in subordinate quantity to quartz and feldspars. It is mostly broken up and shredded though broad plates are not rare. Biotitic alteration of hornblende is in evidence and when such an alteration is present, segregation of iron ore is common; chlorite is also present as a derived product. Sphene occurs in profusion, sometimes in wedge-shaped crystals, some grains of sphene seem to have been derived from ilmenite (*Vide* micro-photo 15. Plate IX). A few grains of apatite are also present. As compared to previous section, apatite is less developed in this section but sphene is particularly noticeable. Epidote is developed at the expense of hornblende and feldspars. Rare grains of glaucophane are also noticed. (*Vide* micro-photo 2. Plate VII).

1. Tottinenidoddi (C.3; 2.9).

(3) *Fine-grained granodiorite.*

Loc :—Gudawaram[1] north tank, Raichur Taluq.

This is a light grey fine-grained rock with a faintly developed schistosity.

Under the microscope it presents a holocrystalline allotriomorphic structure consisting of a preponderance of quartz and feldspars in almost equidimensional grains both exhibiting clasticity. Hornblende occurs roughly in equal proportion to quartz and feldspars and is much torn and shredded maintaining a sort of parallelism. In some instances hornblende shows segregation of iron ore towards the margin. Pœciloblasts of quartz are noticeable in some of the hornblende plates. Rarely biotite is developed at the expense of hornblende. Feldspars are mostly kaolinised. Some of the grains of feldspars have become cleared of their impurities towards the centre and show a clear untwined core. Acid variety of plagioclase feldspars preponderates. Accessory minerals like apatite and sphene are absent. (*Vide* micro-photo 3 Plate VII).

(4) *Granodiorite porphyrite.*

Loc :—Marteswar hill, Kallur,[2] Manvi Taluq.

It is a dark grey rock mottled with white idiomorphic crystals of feldspars giving the rock a porphyritic structure.

Under the microscope the section consists of broad porphyroblasts of kaolinised feldspars and hornblende in a ground mass of shredded hornblende, biotite, crushed quartz and feldspars. The feldspar shows development of secondary albite very clearly. This secondary albite forms clear minute crystals showing incipient twining which can be distinguished under crossed nicols. There is no tendency for any directional disposition of these inclusions, and they occur irregularly distributed. The periphery of the feldspar phenocrysts is invariably crushed while the

1. Gudawaram (B.2 ; 5.3). 2. Kallur (A.2 ; 8.6).

relics of the original kaolinised portions are left in the core. Feldspar crystals occur in broad plates but repeated twinning is not much in evidence. Quartz occurs mostly crushed and with feldspars it forms a mosaic. Hornblende occurs with its characteristic blue-green colour, but much shredded and frayed, sometimes into thin needles. Biotite is also present as an alteration product from hornblende with separation of iron ore. A few grains of apatite are also noticed. Sphene is developed at the expense of ilmenite and is feebly pleochroic. (*Vide* photo 4 Plate VII).

(5) *Acid variety.*

Loc :—Kalmali[1] hill, Raichur Taluq.

This type is well represented in the Kalmali hills. It is a fine-grained dark grey rock with blebs of blue quartz imbedded in the groundmass. The rock reveals also a schistose structure.

Under the microscope the section reveals a highly crushed schistose structure. Roughly rounded and angular fragments of quartz, rarely feldspars, lie imbedded in the groundmass. The bigger grains of quartz show marginal granulation and corrosion. The structure suggested a pyroclastic origin. The groundmass is essentially composed of highly crushed aggregates of quartz and feldspars interspersed with black iron ore and some vestiges of hornblende, mostly chloritised. Iron ore and sphene occur along lines of altered hornblende ; apatite is present. Feldspars are mostly of orthoclastic and acid plagioclastic variety. Albite in phenocrysts shows polysynthetic twinning. Muscovite and sericite are present as derived products. (*Vide* micro-photo 5 Plate VII).

(6) *Intermediate variety.*

Loc :—About a mile west of Gabur,[2] Deodrug Taluq.

1. Kalmali (A.2 ; 8.8). 2. Gabur (A.1 ; 6.3).

Medium to coarse-grained dark grey rock in which white feldspars are prominently developed in a dark background consisting of hornblende and quartz.

The rock section presents a porphyroblastic structure with porphyroblasts of feldspars and of hornblende. The groundmass consists of crushed quartz and feldspars. Hornblende is characteristically blue-green in colour and occupies more than a third of the section and is mostly shredded and frayed. The broader porphyroblasts of hornblende exhibit pœciloblastic inclusions of quartz and feldspars. The feldspars are highly saussuritised and sphene is also developed. Albite-oligoclase variety of feldspars occurs showing plates of polysynthetic twining. In some instances the altered portions of the feldspars have become cleared showing peripheral granulation where the crushed quartz and feldspars form a mosaic. Magnetite has segregated in the crushed zones. Epidote is developed at the expense of hornblende and feldspars. Apatite and sphene are also present. Biotite is developed at the expense of hornblende which is also partly chloritised. An idioblastic basal section of hornblende is noticed with both the sets of prismatic cleavages. This phenocryst is surrounded by crushed and granulated quartz. (*Vide* micro-photo 6 Plate VII).

(7) *Basic variety.*

Loc :—Partipalli,[1] Raichur Taluq.

It is a dark grey medium-grained rock in which some patches show lustre-mottling. In the same hand specimen the texture varies from place to place.

Under the microscope the section presents a granitoid structure. It consists of augite very prominently developed. Sandy brown, purplish to almost colourless varieties of augite are noticed, but even the coloured ones do not show any pleochroism. In places the augite is partly or completely uralitized giving rise to greenish amphibole.

1. Partipalli (B.2;3.2).

The uralitization appears to start from the periphery of the augite crystals, the border being crowded with green actinolitic needles, the alteration gradually proceeding towards the interior. (*Vide* micro-photo 18. Plate IX). Iron ore is abundantly developed in large opaque patches occupying partly or wholly the altered portion of the augite. In some portions of augite biotite has been formed as a derived product in zones where augite has changed into uralite. The green needles of amphibole are seen to penetrate the adjoining feldspars, often occupying their cleavage lines as well as the slip cracks of the neighbouring quartz. The feldspars are mostly plagioclastic and quartz is only developed in minor quantity, mostly adjoining uralitized portions of augite suggesting a separation of silica. (*Vide* micro-photo 7 Plate VIII).

In another micro-section of a similar type of rock from north of Sindhanuru there are some stray instances in which augite appears to pass into biotite the intermediate stages being indistinguishable.

(8) *Epidotised rock.*

Loc :—A mile and a half south-east of Kallur[1] on the path to Malshettihalli, Manvi Taluq.

It is a fine to medium-grained dull greenish grey rock in which the minerals are not easily identifiable by the naked eye.

The rock section presents a clastic structure with highly altered feldspars, greenish hornblende and abundant development of yellowish green slightly pleochroic epidote. Some portions of the section are entirely composed of granular aggregates of epidote. Hornblende has mostly lost its colour and is bleached. Epidote occurs both at the expense of hornblende as well as of feldspar. Quartz occurs mostly crushed in the slip cracks of the feldspar. Both hornblende and quartz also occur embedded in the

1. Kallur (A.2 ; 86).

feldspar while the hornblende itself is pœcilitic with quartz. The feldspars are mostly oligoclase to andesine variety. Some plates of oligoclase have developed secondary albite. Needles of shredded amphibole are commonly developed side by side with epidote. Apatite is also noticed in the section. (*Vide* micro-photo 8 Plate VIII).

(9) *Epidote hornblende rock.*

Loc :—About 1 furlong west-north-west of Dinni, Raichur Taluq.

It is a phanerocrystalline, light greenish grey, medium to coarse-grained rock.

Under the microscope it shows a porphyroblastic structure showing phenoblast of pink feldspar which exhibits peripheral crushing and palimpsest structure. Schistosity is not evident in the hand specimen but under the microscope, there is a tendency for the ferro-magnesians to occupy a parallel disposition. The feldspars are mostly kaolinised and consist of orthoclase and albite, the latter showing fine polysynthetic twining. The groundmass consists of a mosaic of crushed quartz and feldspars interspersed with shreds and plates of blue green hornblende often changing into epidote. Some of the feldspars show zonal structure. Apatite is also present. Epidote is abundantly developed and rarely biotite as derived products of hornblende. Black magnetite and opaque brown hæmatite are derived as a result of segregation from altered hornblende. (*Vide* micro-photo 9 Plate VIII).

(10) *Granulitic schists.*

Some of the Dharwar hornblende rocks show various stages of granulation from incipient rounding of edges of hornblende flakes to typical development of their granular aggregation, in which hornblende, quartz and feldspars, maintain a parallel disposition.

1. Dinni (B.2 ; 1·4).

An early stage of granulation is marked in a specimen south of Timmapur,[1] Raichur Taluq, where only the edges of the hornblende flakes are rounded into definite outlines and quartz and feldspars show a tendency towards granulation.

A rock section from Amrapur,[2] Deodrug Taluq, shows an advanced stage of granulation. Hornblende occurs in stunted prisms with almost rounded outline interlocked with granular quartz and feldspars.

A further advanced stage of granulation is shown by rock taken from near Monkey shaft, Wandalli. The hornblende flakes have become more broken up with rounding of the edges and occur interlocked with crushed granular quartz and feldspars. Occasionally these granulated hornblende prisms crowd in patches showing a general optical continuity. This clearly indicates that these patches once formed portions of some bigger hornblende crystals. A few grains of augite are seen. Ilmenite also occurs with sphene. (*Vide* mirco-photo 10 Plate VIII).

PSEUDO AND QUASI CHARNOCKITES.

From the mineral assemblage of the granodioritic rocks referred to above, an interesting relation is suggested between some of these rocks and those described by the Mysore geologists as pseudo-and-quasi charnockites M.G.S. Records Vol. IV, page 51 and Vol. VIII, page 117).

Section No. 2 from west of Tottinenidoddi reveals the following minerals :—

Hornblende, feldspars, biotite, sphene, apatite, pistacite· This mineral association compares.with that of the pseudo-charnockites ; but it must be noted here that fresh augite is absent unlike as in Mysore samples.

Sections Nos. 1 and 3 do not show sphene ; so this specific absence of sphene makes them comparable with the

1. Timmapur (A1; 8.4). 2. Amrapur (A.1; 4.3).

members of the quasi-charnockite rocks. On the other hand the presence of ilmenite, apatite, and some stray needles of zircon in these sections, point, not only to their affinity to quasi-charnockites, but also, to the type charnockites. But it may be noted here that garnet is conspicuous by its absence in these sections. The absence of garnet and hypersthene seems to suggest that the metamorphism of these rocks in the Raichur Do-ab is of a lower grade than that which produced quasi-charnockites of Mysore or the type charnockites.

The acid varieties of granodiorites show analogous mineral association to the acid types of quasi-charnockites from Mysore,* as the following comparative statement will show :—

Section.	*Section J/824 from Mysore*
Loc :—Upanal,[1] Raichur Taluq.	Loc :—unknown.
1. Holocrystalline with a more or less crushed structure.	Holocrystalline, crushing less than in the other section.
2. Biotite, mostly baked.	Biotite, mostly baked.
3. Hornblende mostly altered to chlorite.	.. ..
4. Magnetite.	Magnetite.
5. Apatite.	Apatite.
6. Quartz.	Quartz.
7. Feldspars, more orthoclase than albite.	Feldspars, more albite than orthoclase.
8. A few grains of epidote.	A few grains of epidote.

It is thus seen that except for the presence of chlorite derived from hornblende there is essentially no difference between the two type members.

* Our thanks are due to Mr. B. Rama Rao of the Mysore Geological Survey for kindly ending to us a few of the type Quasi-Charnockite for this interesting comparative study.

1. Upanal (B.2 ; 5.2).

The intermediate and basic varieties of granodiorites show similarity with the corresponding members of the quasi-charnockite group from Mysore. It must be here noted that in the Mysore specimens, apatite is very conspicuously developed into big crystals ; while in these members though there is an abundance of this mineral, apatite occurs in grains and needles of smaller size. The conspicuous absence of garnets in the granodiorites of the Raichur Do-ab has already been referred to.

Besides the above, the following rock types also deserve mention in view of their interesting peculiarities.

DYKE ROCKS.

(11) Dolerite dyke.
(12) Epidiorite dyke.
(13) Xenolithic dyke.
(14) Porphyritic dyke.

(11) *Dolerite dyke.*

Loc :—About 2 miles south of Kurdi,[1] Manvi Taluq.

It is a medium-grained dark rock. Under the microscope the section shows a holocrystalline medium texture with a typical development of ophitic structure. It consists of sandy brown, to pale purplish to almost colourless augite. The coloured varieties are not pleochroic. Alteration of augite to amphibole is not seen. Long blades and laths of plagioclastic feldspars mostly of basic varieties are very conspicuously developed in ophitic relation to augite. Magnetite and rarely ilmenite are present. (*Vide* microphoto 11 Plate VIII).

(12) *Epidiorite dyke.*

Loc :—About three miles west of Sasnur,[2] Gudwal Samasthan.

1. Kurdi (A. 2 ; 8. 2). 2. Sasnur (D. 2 ; 7. 4).

It is a medium-grained dark greenish grey rock. Under the microscope the section presents a holocrystalline ophitic structure. The feldspars are basic plagioclastic variety and are mostly kaolinised. Rarely feldspar has altered into epidote. Augite is in sandy brown and purplish plates much altered into greenish amphibole, the alteration proceeding from the periphery. Sometimes the whole of the augite is converted into uralite. Ilmenite with leucoxene, as well as magnetite are present. (*Vide* micro-photo 12 Plate VIII).

(13) *Xenolithic dyke.*

Loc :—South of Aruvalli,[1] Manvi Taluq.

It is a dark greenish grey medium-grained rock with cognate xenoliths of reef quartz and gneissic fragments.

In this section it shows a holocrystalline structure in which hornblende occurs both as porphyroblasts and small plates. The feldspars are mostly of basic plagioclastic variety which are highly saussuritised. There are big inclusions of quartz xenoliths round the margins of which hornblende crowds to form a thick border. The quartz xenoliths do not show much crushing. Some of the quartz grains have a granulated outline due to corrosion. A sort of feathery structure is developed in quartz which with the feldspars has entered into a micrographic intergrowth. Epidote is also present as a derived product from both hornblende and feldspars. (*Vide* micro-photo 13 Plate IX).

(14) *Porphyritic dyke.*

Loc :—South of Uppal,[2] Gudwal Samasthan.

It is a dark grey medium-grained rock with conspicuous development of broad greenish white porphyritic feldspars. A microsection reveals purplish to colourless augite plates in ophitic relation to feldspars. The feldspars are mostly basic plagioclastic variety. These occur as phenocrysts

1. Aruvalli (B.2 ; 1.2). 2. Uppal (C.3 ; 7.9).

as well as in the groundmass. In some of these feldspar phenocrysts augite in well defined crystal outline is also rarely found enclosed. The plagioclastic feldspars have become highly saussuritised and portions have become clear. Epidote is developed along twin planes of feldspar phenocrysts. The augite in some instance has altered into amphibole and biotite with the separation of magnetite. (*Vide* micro-photo 14 Plate IX).

Discussion.

In many localities, from the field relation, it is clear that the Dharwar schists have taken parallel structure under the influence of the Peninsular granitic invasion and as a result have been squeezed into narrow bands. In addition to the normal metamorphic effects observed in the Dharwar bands of the western part of the Raichur Do-ab, we find in the eastern part some pronounced phases of assimilation and reconstitution. The effects of this relation are clearly impressed in the mineralogical reconstitution of the Dharwar bands by the development of the wholesale, or partial crystalloblastic growths of the reconstituted minerals. The rocks into which the Peninsular Complex have intruded are now represented by highly metamorphosed igneous schists—both type Dharwar schists and their granodioritic phases.

The study of the metamorphism of the granodioritic formations is based on a few postulates.

1. The Dharwar rocks were original basic extrusions in form of lava flows, sills and intrusive sheets or laccolithic masses with occasional basic dykes.

2. The original mineral constituents of these basic flows were in all probability pyroxene, plagioclase feldspars and ilmenite with a little quartz.

3. Acid invasions also took place between intervals of the successive basic series, the former now

being represented by quartzites, quartz schists and quartz porphyries.

The object of the discussion that follows is to suggest that the granodioritic rocks have been derived as a result of regional metamorphism, partly by reconstitution of the type Dharwars, and partly by assimilation of the type Dharwars with intrusive acid rocks. This proposition is supported both (*a*) by the structural peculiarities of the granodiorite rocks in relation to the Peninsular Complex as well as (*b*) by the mineralogical changes manifested by the rocks.

Granodioritic series.

In the granodioritic rocks we approach a stage of transformation in which the original Dharwar basic flows with associated acidics have been changed into rocks of coarse to fine-grained texture, partly by assimilation and partly by reconstitution. To what extent there has been an assimilation of material from the Peninsular Complex is not easy to say; but, it seems that this could not have been appreciable. It appears that the basic and the acidic members of the Dharwar series have undergone a reconstitution and that in regions which were originally characterised by the presence of acidic members we now get siliceous types of schists. In the western portion of the Raichur Do-ab, the Dharwar type schists are abundantly developed in the main Maski and Kushtagi bands of schists; but along the margin of those main bands these granodioritic members are only rarely found in apparently isolated outcrops. In consequence, their relation to the type schists and the nature of their metamorphism could not be clearly studied in that region. In the eastern portion of the Raichur Do-ab, however, the occurrence of the granodioritic phase of rocks over a considerable area, with occasional intercalations of type schists, definitely attaches a far-reaching significance to their secondary evolution which can hardly be lost sight of. The field relation of the type Dharwar schists of the western part of the Raichur Do-ab has already

been discussed in the previous Journal. (*Vide* Jour. Hyd. Geol. Survey Vol. II, pt. i).

More detailed work is necessary to give a definite outline of the successive mineral changes in these granodioritic members; but it is sufficiently clear from field work and petrological studies that these rocks must have been derived through the various stages of metamorphism of the pre-existing type Dharwars and their associated acidics, at times by fusion and assimilation and at times by internal reconstruction.

Metamorphism of the basic flows.

Before entering into the details of the various stages of the changes which the granodioritc rocks have undergone, it is important to recognise that the hornblende schists, out of which the corresponding granodioritic rocks were derived, have originally resulted from pyroxenic flows.

This hornblendization of pyroxene is suggested by the possibility of physico-chemical changes as exemplified in a minor scale by analogy drawn from the dolerite dykes of the post-gneissic age, which have in several places since become converted into epidiorites.

Paramorphic changes.

Under ordinary atmospheric pressure but under a continued high temperature pyroxene is liable to be converted paramorphically to hornblende (actinolite variety). Dr. Smeeth* regards the hornblende of the hornblende schists to have been derived from the original augite of the basic flows. The metamorphism appears to have been uniform and complete, but augite also, now and then, occurs; this latter is shown to be secondarily derived from hornblende. This is clearly suggested by the locality of the occurrence of augite. Where this secondary augite occurs, the schists are invariably associated with some later acidic intrusives. So he concludes that this secondary

* W. F. Smeeth "Secondary Augites" Bull. No. 3 Mys. Geol. Survey (1903).

change of hornblende into augite is due to a later molecular re-arrangement. The hornblende of the type schists is green to blackish-green and in thin sections bluish-green to yellowish-green.

Metamorphism of dyke rocks.

Moreover, the examination of basic dolerite dykes frequently reveals the fact that these dykes, originally consisting of augite and plagioclase, have undergone in places mineralogical transformation from augite to hornblende.

The transition from dolerite to epidiorites is well exemplified in the regional series of east to west dykes which cut the Peninsular gneisses specially in the Gudwal Samasthan. (*Vide* map). Transitions can be traced from an altered dolerite composed of plagioclase and augite, to rocks which are distinguished as epidiorites, (*Vide* micro-sections). The schistose structure, when developed, is parallel to the strike of the dykes and is more pronounced near the margin than in the central portion.

These epidiorites are essentially plagioclase-hornblende rocks in which quartz, and ilmenite with leucoxene occur. The original ophitic texture of dolerites in these dykes is frequently preserved, although the augite may have been largely replaced by green hornblende. (*Vide* micro-photo 12 Plate VIII). In other cases however, this ophitic character is more or less lost, the feldspar having been broken up along with the augite into irregular patches, the latter however still maintaining an optical continuity. Occasionally the old turbid feldspar substance disappears and a secondary water-clean albite is developed. These mineralogical changes and structural characters are often well exhibited in some of the sections of altered dolerite dykes from Gudwal Samasthan. Pyroxene is often replaced by fibrous amphibole by uralitisation. The alteration to the fibrous amphibole proceeds inward from the periphery of the pyroxene crystals. (*Vide* micro-photo 18 Plate IX).

a. Structural peculiarities of the granodioritic rocks in relation to the Peninsular Gneissic Complex.

Tectonic aspect of the Dharwar schists in relation to the Granite Batholith.

A small digression may here be made to bring into prominence the broad structural dynamic features of the Dharwar schists in relation to the Peninsular gneisses. Broadly viewed the Dharwar series rest on the Peninsular gneisses in this area.

In the previous Journal, Vol. II, pt. i, pp. 115 and 119 reference has been made to the emplacing batholithic* mass constituting the Peninsular Gneissic Complex.

It is evident that the Peninsular Gneissic Complex has resulted from the progressive squeezing out of the liquid portion of granite magma consolidating under stress. This great granitoid mass can be separated into two major groups by means of the dominant feldspars. In the first group, white soda-bearing plagioclase-albite and oligoclase in addition to orthoclase occur; in the second pink alkali feldspars (orthoclase and microcline) predominate. The two groups have been called the Grey and Pink series, respectively. Pegmatites are associated with both the series; white binary aplites and white pegmatites are the frequent associates of the Grey series; whereas, pink aplites and pink pegmatites form the prominent acidics of the Pink series.

The contact relation of the Grey and Pink series with the basic Dharwar flows, presents certain individual characteristics. For instance, the Grey series do not show penetrating intrusion into the Dharwar basics in the sense of sending tongues and apophyses in the invaded rocks. It is not however, suggested that the acidics of the Grey series do not find injections in the Dharwar schists which in fact may often be noted. What is here specially emphasised is, that the mode of contact is, more of less, of the nature

* Origin of Igneous Rocks. R. A. Daly. pp. 261-262 (Ed. 1914).

of regional fusion (Anatexis of Sederholm) and of part assimilation. Generally, the type grey gneisses are not found to intrude and cut into the typical Dharwar schists. A series of assimilated and reconstituted rocks are formed between the Dharwars and the type Grey members. Thus, we find a series of white acidic rocks to have been produced, which may be termed hornblende granite gneiss. This hornblende of the assimilated gneiss gradually diminishes in quantity in the rock which shades ultimately into normal biotite gneiss. The Pink series of gneisses, on the other hand, show many features of penetrative intrusion, not only into the members of the Grey series, but also into the Dharwar type schists.

From this initial contrast in the general mode of contact relation with the Dharwar schists, it seems that the fundamental controlling forces inducing their broad mineralogical differentiation into the Grey and the Pink series, must have differently actuated the great batholithic mass that found emplacement below the overlying Dharwar basic lavas. This broad mineralogical differentiation into the Grey and the Pink series must be considered as a function of earth forces evidenced at a period when the alkali-granite batholith was consolidating. As a result of squeezing, portion of the unconsolidated or partly consolidated mother liquor found differentiation in respect of space and time. As a corollary to this physico-chemical control, the Grey series almost always formed the floor of the Dharwar schists with occasional assimilation and fusion with the Dharwar schists. It is commonly noted in the field that the foundered masses of xenolithic schists do not show complete fusion, but only a reconstitution into a hornblende gneiss, whereas the Pink members developed into injection-series of rocks penetrating not only into the Grey series, but also into the Dharwar schists. *Lit-par-lit* injections in the form of pegmatites and aplites of the Pink series into the grey gneisses, as well as their thorough permeation in the schist band, always point to an outstanding structural feature which is characteristic of these Pink series.

Lateral invasion of the gneissic complex is frequently represented by the Grey series which form bays into the belt of Dharwar schists; but at the contact between the Grey series and the Dharwars, the Pink series often finds a favourable lodgment in form of acidic veins of minor magnitude. The Pink series, in large outcrops is, however, generally found to occupy the marginal area of the Grey gneissic series. Intermingling zones of both Grey and Pink series is not uncommon in the Grey gneissic zone, where, an insensible gradation with greater preponderance of pink feldspar may be easily observed passing from the dominant grey to the dominant pink rock. Essentially, the field evidence suggests that such Grey series pass to the Pink series on a regional basis, the contact relation being impossible to demarcate. Attention may be drawn here to the fact that this insensible gradation between the Grey and Pink series is essentially confined only to the older, coarse-grained type of rocks of both the series, and not noticeable in the later pegmatites and aplites of either of the series.

Tangential compression.

Tangential stress, on a gigantic scale, upon the batholithic mass must have had an extensive structural significance. This dynamic factor clearly impressed a strong directional effect on the overlying basic flows as well as on the semi-consolidated plastic granite gneisses in which the schists partly foundered and through which they were dragged along. It follows that the great folding-processes in the granitoid masses must have profoundly affected the schists. The schist was repeatedly torn asunder from the main solid belts so as to get entangled, or engulfed in the plastic flow of the granite mass. The shredded disposition of the schists, in many places now observed, is only a faint evidence of this stupendous process. The greater portion of the original schist mass has long since been eroded and only these denuded stumps of the schists are now lying exposed.

The physiography due to the differential erosion to which shredded patches of schists owe their residual

existence, may be illustrated. The probable nature of structural folding of the composite gneisses of the Peninsular Crystalline Complex in relation to the Dharwar basic flows, is suggested in the block diagrams. (*Vide* diagrams 8-11 Plate V.).

It will be evident from the diagrams that the Dharwar flows were intensely folded into narrow squeezed belts within the folds of the gneisses, forming linear bands of schists with upturned edges. The grey gneisses seem to have folded themselves at its contact, with marginal assimilation. The pink gneisses insinuated themselves not only into the folia of the schists but also sent repeated injections in the Grey series. It is therefore inferentially suggested that the crumpling, folding, and faulting of the Dharwar bands are probably more due to the cataclastic effects introduced by this Pink series of gneisses rather than to the peaceful emplacement of the granite during the evolution of the Grey series. It is probable that these gneissic rocks once formed prominent hills of high elevation and of great magnitude. They played an important part in the erosional cycles that followed since the Eparchæan interval, introducing peneplanation of these gneissic rocks together with that of the Dharwar schists. It may be noted here that the marginal areas of the Grey series of rocks are flanked by the pink gneisses and pink porphyry granites of the Kistna and the Tungabhadra rivers. These feldspathic rocks are more susceptible to the influence of weathering agencies by disintegration and decomposition.

The geo-physical aspects inferentially drawn above of the Dharwar basic flows with respect to the great batholithic mass may be regarded only as a broad generalisation ; so, like all generalisations, may be considered with reservation. Nevertheless, the basic principles therein enunciated will have always to remain substantially valid. In the light of these limitations, the structural relation of the granodioritic rocks may now be considered.

Granodiorites due to piezo contact metamorphism.

Structurally, the distinction drawn between an ortho-gneiss and an ortho-schist is only one of degree. The former is rather a coarse-textured rock with a broad parallel disposition of minerals of which it is composed, whereas the latter is usually a rock of medium texture with a somewhat fissile or contorted structure.

A glance at the map will show that the Dharwar band, which mainly consists here of granodioritic rocks, follows a crude strike which controls the trend of the belt. Evidently the belt has been subjected to stress and squeezing due to gneissic invasion from both the flanks, which strongly impressed its parallel tectonic effects on the belt and determined its shape.

Whether the belt may be regarded as a distinct plutonic entity, analogous in origin to the Charnockite series of rocks of South India, or as a regionally sheared mass of metamorphic rocks, in either case, these rocks have been evidently formed as a result of tangential stresses acting upon a molten or plastic material under conditions of high temperature and pressure. The former possibility that these granodioritic rocks may be regarded as distinct plutonic invasion, is not however, borne out by field evidence. The contact of type schists with these granodioritic forms has nowhere been sharp and distinct; on the other hand, a gradual insensible gradation is easily noticed from coarse to fine-grained texture and ultimately to fine-grained siliceous forms and to the type schists.

To what extent granitic bodies have contributed to the final assimilation and reconstitution of the granodioritic rocks is a factor which cannot be determined with certitude: at the same time it may be presumed that these could not have been of any great magnitude, except perhaps along the contact and rarely in some localised areas. Some of the gneissic outcrops in the neighbourhood of Kallur amidst granodioritic rocks may be instanced as example of localised assimilation.

The alignment in the distribution of hills flanking the belt of the granodioritic rocks on either side, to which attention was drawn in the early part of this report, indicates the immensity of the dynamic agencies to which this system of rocks had been subjected. Thus the conception which has been termed piezo-crystallisation by 'Weinschenk,'* seems to find an application here "the slow consolidation of igneous rocks, plutonic or volcanic, under conditions of tangential stress." This effect was evidently produced when Peninsular gneissic material was intruded into the original basic Dharwar flows undergoing folding. Owing to the slowness of cooling under conditions postulated, the invaded rocks were subjected to piezo-contact metamorphism and developed into coarse to medium-grained rocks.

When the invaded Dharwars were already at high temperature, subsequent pegmatitic intrusion also took place in the form of *lit-par-lit* injection. The injecting aplites and pegmatites permeated all possible zones of weakness and intertwined with the intruded pre-existing rocks, more especially along the contact margin. In several localities, these pegmatites have been observed to overlap the granodioritic outcrops. Such a feature is well represented on the track from Turkandoddi to Partipalli. (*Vide* photo 5 Plate IV).

Textural relation of the granodioritic rocks.

These granodiorites range from fine-grained schistose or massive hornblende rock through hornblende-porphyrite with an aphanetic groundmass, to even-grained diorite-granulite on which pitted weathering is characteristic. The texture of the granodiorite is locally uniform, but generally, it is medium to fine. Coarse-grained members are usually transitional into hornblende granulites. The rock is fresh looking and only a little sheared. No sharp boundaries can be detected between the hornblende granulites, gabbros and diorites on the one hand, and the horn-

* The Petrology of the Igneous Rocks by Hatch and Wells 1926 p. 386.

blende and chorite schists, on the other. Microscopic evidence indicates that in some instances, at least, they were original gabbroid rocks, now partly or completely recrystallised.

Contact gneisses in relation to the granodiorites.

The marginal zones of the Peninsular gneisses at the contact of the granodiorites are cut, at many places, by younger, massive or coarse-grained binary granites. These are nearly free from dark minerals and grade into granite pegmatites—a variety of light grey to pink granite which at many places, is only faintly gneissic. Locally pink aplite dykes are also present along the contact.

The contact of pegmatites and aplites with the granodiorites and typical schists indicates a slow cooling condition to have been induced not only in the veins of aplites and pegmatites, but also, in the invaded rock. The effect is that reconstituted schists by assimilation have been formed in these areas with coarse granular texture and gneissic structure. The contact rock is granulitic. But this texture of rocks in the schist is neither universal nor constant. This aspect has perhaps a dynamic relation to the gneissic ridges that occur along the margin, where greater evolution of heat might have induced conditions of pronounced crystallinity. This feature is well marked to the east of the Railway line N.W. of Matmari, as well as along the western boundary of the granodioritic band. In certain areas, however, where pegmatites and aplites predominate and no great stress effects are noticeable, only fine-grained varieties of granodiorites have developed. This is specially noticeable along the north-western half of the granodioritic band.

There are cases where hornblende schists are included in the granitic area and also conversely cases where granite is included in solid hornblende schist area. In either of these occurrences, the interaction of the marginal schist with granite has been marked by assimilation of horn-

blende material into the granite. In such instances the granulitic texture of the contact rock gradually become coarser, as the granite is approached, and the rock thus formed may be termed a coarse hornblende granite or a quartz diorite. The granulitic texture however soon gives place to an interlocking granitic texture when the rock type finally shades off with the diminution of hornblende and increase of biotite into the surrounding biotite-granite gneiss.

b. Mineralogical changes shown by Granodioritic rocks.

It is commonly observed in the area, that the granodiorites are mostly basic in composition. The minerals met with show a preponderance of magnesia, lime playing a very subordinate part. There is a high percentage of silica and considerable amount of alumina and soda. Metamorphic minerals formed by silicates of alumina such as andalusite, kyanite, sillimanite, cordierite, and staurolite—are conspicuously absent. This fact precludes the possibility of ascribing a sedimentary origin to these granodioritic rocks. The rocks show a series of phaneric representatives of coarse, through medium to fine-grained euhedral, anhedral and subhedral crystal forms, and consist occasionally of equidimensional quartz but mostly of tabular feldspar and ferromagnesians of irregular shape. The minerals show granitic, rarely porphyritic and pœcilitic structures. Directive structure has been clearly produced by the flow in the melt during its crystallisation, and often juxtaposition of different textures. In this connection the following quotation from Tyrrell* elucidates the limitations under which metamorphism may be conceived to have affected the rocks.

" Metamorphic reactions go on in the solid state. The rocks are not melted or dissolved as a whole, and only a small fraction is in solution at any given time. That

* The Principles of Petrology, by G. W. Tyrrell. pp. 261-262. (Ed. 1930).

is to say, the amount of the solid phase in metamorphism is always overwhelmingly in excess of any other phase, liquid or gaseous. This has important effects on the texture of metamorephic rocks ; and the diffusion of substance, with the consequent mixing of different materials, must also be extremely limited."

Line of mineralogical changes followed by the granodioritic rocks.

From basic silicate melts originally represented as Dharwar schist formations, magnetite or hæmatite easily separated out in the presence of magnesium, so also sphene, when lime and titanium were present. Following the later stages of uralitisation, iron ore is dominantly produced by recrystallisation. In presence of feldspar and hornblende, chlorite or biotite is produced by extraction of alumina from decomposing feldspars and ferromagnesian constituents, from the hornblende. By extraction of lime and alumina from the plagioclase, secondary epidote is mainly derived. The mineralogical changes of the ferromagnesian minerals is easily followed under the microscope. The augite, when present, is partly replaced by hornblende and the latter, in some instances, by biotite. Chlorite may be derived from any or all of the above minerals. But such chloritic alteration is rather rare in the reconstituted rocks.

The formation of epidote seems to follow two lines of development. Epidote is either developed (1) from the alteration of hornblende or (2) by saussuritisation of plagioclase feldspars, oligoclase and andesine varieties. Thus it appears that the formation of epidote is a linking process by which mineral transformation between the ferromagnesians on the one hand and the soda-alkali feldspars on the other, has been established depending for its lime and alumina content upon the decomposition of either of the series or in part, upon both the series.

The other important minerals that have frequently lent themselves for transformation are quartz and feldspars.

In the metamorphism of quartz the following stages are noted. Due to strain the quartz often shows undulose extinction. Progressive stages are marked by

Quartz.

1. Peripheral crushing
2. Complete crushing (mortar texture)
3. Crushing with granulation
4. Complete recrystallisation into crystalloblastic growths out of the crushed grains.

Both orthoclase and soda-alkali feldspars like albite, oligoclase and andesine and rarely labradorite, are identified. Microcline is a slow-crystallisation mineral. This is traceable in the reconstituted acid rocks cooled at a very slow rate, in place of orthoclase.

Feldspars.

(*a*) Orthoclase partly or wholly decomposed into kaolinised products with the development of flake of sericitic mica, is often marked by peripheral granulation, when the kaolinised product is cleared from the portion thus granulated. Sometimes the whole of the orthoclase is crushed into smaller grains and forms a fine granular texture with similar crushed grains of quartz resulting in a quartz-feldspar mosaic. At times the central portion of the feldspar is elongated with peripheral granulation showing a phacoid texture.

(*b*) The alkali-plagioclase series is more susceptible to mineralogical alteration than the potash feldspar.

Albite is frequently kaolinised. On a slightly advanced stage, the decomposed product is cleared towards the marginal part and the mineral section appears as water clear crystal. Frequently the peripheral zone is crushed. Granulation of the crushed zone by recrystallisation is a common feature.

Sometimes a higher calcic stage is marked, when, the albite passes from oligoclase to andesine. When andesine largely occurs, epidote is frequently formed as an alteration product deriving lime and alumina from the plagioclase for its constitution. Secondary albite is developed along the thin twinning laminæ disclosed under high power of the microscope.

The main mineral constituents of the granodioritic series may be enumerated as follows :

1 Quartz.
2 Feldspars-microcline, orthoclase and plagioclase chiefly of the sodic varieties such as albite, oligoclase and andesine; labradorite rare.
3 Amphiboles (actinolitic, or tremolitic and at times uralitic), rebeckite and glaucophane also occur.
4 Rarely muscovite, but frequently biotite and chlorite.
5 Augite.
6 Apatite, magnetite or hæmatite, sphene and zircon in rare cases. Secondary epidote or zoisite are common.
7 Magnetite and hæmatite occur as derived product from biotite, hornblende and augite.

From the assemblage of minerals shown above, it may be noted that a strong sodic affinity is manifested in the rocks. Besides quartz and potash feldspar which both occur in subordinate quantity, in crushed form, or in phacoid texture, sodic feldspars like albite, oligoclase and andesine always play a very important role. Biotite is frequently developed; ferromagnesians like soda-amphiboles and soda-pyroxenes have also figured. Apatite is a constant accessory and is abundantly present in the rocks. Zircon has rarely developed. Magnetite is sometimes primary. Ilmenite occurs as a primary constituent of the schist with its usual decomposition product, leucoxene. In some of the granodioritic rocks sphene is developed with ilmenite. In crushed rock, sphene is

formed at the border of the ilmenite grains with recrystallisation and separation of silica. In rare cases sphene is primary, probably having been introduced with granitic intrusions. Sphene derived from ilmenite is very frequently found in granulites. Pyrite rarely occurs. Epidote is recognised in the rocks as a decomposed product from feldspars and sometimes as veinlets in the country rock. This mineral is not found in the homogeneous type schists but is frequently noted in altered schists intercalated with acid bands. Epidote is also found in association with augite and hornblende. In the highly coloured varieties it is pleochroic. At times zoisite is developed with its weak double refraction and low interference colour.

Augite is pale purplish to colourless, light to dark sandy brown in thin sections. In some slides prepared from the rocks exposed towards the eastern margin of the granodioritic band, near Sindhunuru, retrograde metamorphism is revealed by the augite. This augite is of pale brownish to purplish tint and is partly replaced by green hornblende. The latter shows alteration paramorphically to biotite. In the mineral, the optical continuity between hornblende and biotite is still maintained. This series of reaction indicates that the augite presents evidences of alteration both into green hornblende and also into biotite.

Hornblende.

The hornblende in these rocks shows elongation parallel to the schistosity, being developed in ophitic growth with feldspars and rarely quartz. A large amount of hornblende is due to the conversion from augite. With shearing effects such hornblende is often granulated and its subsequent recrystallisation is marked by pœcilo-blastic or sieve-structure with separation of silica. The hornblende is torn asunder into thin shreds and patches with fritted edges moulded with or enclosed in a groundmass of quartz and plagioclase feldspar mosaic. When the granulation of the hornblende has been very severe, magnetite and hæmatite often leach out from along the cleavage lines and roll into granulated shreds, the rock so formed

becoming granulitic. A part of the schist formation thus results into granulitic rocks.

Granulitic types of schists.

The main schist band derived from the ancient lava-flows do not possess an original granulitic texture; on the other hand, instances are frequent in which it can be easily seen that the larger feldspars have been broken up, the quartz has been crushed and the hornblende is represented as parallel bands of stunted hornblende prisms due to crushing and resorption of the frayed edges. (*Vide* micro-photo 10 Plate VIII).

C. *Nature of metamorphism.*

A few words may be added here regarding the degree of metamorphism undergone by the granodioritic rocks. From what has been said regarding the modifications of the minerals contained in the rocks and their internal structure it is evident that the rocks of the area have been clearly marked by the mineralogical transformations of such a nature as to be usually associated with epi-and meso-zones of regional metamorphism under conditions of low or moderate temperature and directional stress. Typical index minerals of high grade metamorphism to define zones, facies or grades of the metamorphic process, however, have not been made out. High temperature and pressure minerals characteristic of hypo-zone are only very rarely developed. Garnet is not present. Augite occurs rarely and hypersthene has not been noted.

A comparative study of the mineral assemblage in Dharwar rocks is of interest.

1. Homogeneous Hornblende Schists :—
   These hornblende schists essentially consist of plagioclase feldspars, hornblende and ilmenite with a little quartz.

2. Altered Hornblende Schists :—
   The original homogeneous schists may be conceived to have been contaminated by two causes

a. Contamination may be due to marginal contact of the solid belts with gneisses.

b. Contamination due to acid granitic injections in the body of the schists.

Examination of the altered schists under the microscope reveals the presence of secondary hornblende derived from augite, biotite derived from hornblende, sphene from ilmenite, secondary magnetite, epidote derived from hornblende, biotite or plagioclase feldspars, pyrite, calcite, apatite and rarely zircon.

Dr. Smeeth claims that the presence of sphene, biotite epidote, calcite, apatite, all in the altered schists, may be regarded to have been derived as a result of acid granitic intrusions in the homogeneous hornblende schists.*

3 Epidiorites.

The mineral constituents of the dykes of the Dharwar formations as well as some of the doleritic dykes of the post-gneissic age which have undergone mineralogical changes and are now converted into epidiorites, may also be compared. The mineral assemblages of such dykes may be enumerated as follows :—Augite, quartz, ilmenite, leucoxene, hornblende, biotite and plagioclase. The augite is converted into hornblende as in the case of hornblende schists.

4. Granodioritic rocks.

It may be noted here and as has already been mentioned before, that all the minerals claimed as derived in the altered schists due to acid granitic injections are also present in these granodioritic rocks. Besides these, some additional varieties like soda-amphiboles—rebeckite, glaucophane—are also developed. This association of minerals therefore goes to suggest

* W. F. Smeeth. " Secondary Augite " Mysore Geological Survey Bull. 3, pp. 30-31

that the granodioritic rocks may equally be considered to have been derived by part reconstitution of the original material and part assimilation of acid granitic intrusions. The presence of an excess of quartz and potash feldspar, besides a series of acid plagioclase varieties, soda-amphiboles and pyroxenes, are strongly suggestive of a reconstituted rock. As has already been pointed out elsewhere, in the granodioritic zone quartz veins are rarely developed but in the type chlorite and chloritised hornblende schist area, intimately associated with the same band, quartz veins have been frequently found. This is an evidence to suggest that the acid fine-grained types of granodioritic schists in many cases at least, have been produced as a result of assimilation. The fragmented character of the blue blebs of quartz assimilated from original blue to pale blue quartz veins in a groundmass of crushed mosaic of quartz and feldspar in the Kalmali pyroclastic rocks, is strongly suggestive of the veiw that at least these rocks must have been derived from the material furnished by the acidic and basic representatives of the Dharwar formations as a result of local melting.

Age of the granodioritic rocks.

A few remarks may here be added regarding the age of evolution of these granodioritic rocks. The structural features manifested by these rocks are accountable to later earth stresses causing plastic deformation and mineralogical alterations.

The relation of the autoclastic conglomerates to the Dharwar schists at Palkanmardi and their mode of origin has been discussed in detail in Jour. Hyd. Geol. Surv., Vol. II, pt.i, pp. 105-111. Similar autoclastic masses like those of Palkanmardi in a basic matrix have also been mapped in the granodioritic area towards the southern parts of the Gadwal band. Numerous tongues and apophyses of

pegmatoid gneisses are seen to have penetrated into pre-existing basic rocks and these were subsequently disrupted by shearing stresses and heat.

The schisted character of the granodioritic rocks in conformity to the strike disposition of the main type schists, their mode of occurrence in shredded patches within the gneissic area, their intimate association with or close proximity to the type Dharwars, all, therefore, suggest that the period of their metamorphism must be relegated to an age contemporaneous with the activity of the Peninsular Crystalline Complex.

Pseudo and quasi-charnockites.

Some types of rocks similar to the granodiorites of this area have been described as pseudo-and quasi-charnockites by the Mysore Geologists. (Records: Mys. Geol. Surv., Vol. V., p. 51 and Vol. VIII., p. 117 *et seq.*) The reason for naming such rocks as pseudo-and quasi-charnockites in Mysore has been suggested by the absence of hypersthene. The pseudo-charnockites are characterised by the presence of fresh augite, hornblende, feldspars, quartz, sphene, pistacite and apatite; while quasi-charnockites are distinguished by the absence of sphene; but the later shows an invariable association of ilmenite and apatite, rarely zircon; garnets are also present. This association of minerals seems to link the quasi-charnockites to the type charnockites, it being presumed that due to conditions of low temperature, hornblende has developed instead of hypersthene in the series.

In the examination of the granodioritic series we find a similar mineral assemblage to that of the pseudo-charnockites, the only difference being that augite has rarely been developed.

Rocks similar in mineral assemblage to quasi-charnockites are also present, where the absence of sphene is noted. But there are other instances where the typical assemblage of minerals of the quasi-charnockite series, such as ilmenite, apatite, and zircon, is noticeable in association with sphene; but garnet is conspicuously absent.

It therefore appears that the granodioritic rocks of the Raichur Do-ab with the so-called pseudo-and quasi-charnockites as types in the group, can only be regarded as of metamorphic origin produced by assimilation of acidic intrusion and reconstitution of pre-existing rocks under heat and stress. A primary igneous origin, connected with any plutonic activity, cannot be ascribed to them. Attention may be drawn to the fact that Holland regards the charnockites as of igneous origin in which various stages of differentiation have been established. (G.S.I. Mem., Vol. XXVIII)

In this connection the views of Vredenburg* suggesting a metamorphic origin of the charnockites from pre-existing Dharwars are interesting. His valuable arguments deserve due consideration and the whole subject is worth a closer study.

Soil and Sub-soil.

The area covered by Dharwar series consists almost completely of a thick mantle of black cotton-soil. The depth of this soil mantle varies from a few feet to sometimes 20 or 30 ft. This thick mantle of soil obscures the observation of the underlying rocks and it is mostly in nullah cuttings that outcrops facilitate the mapping of geological formations.

Generally, below this soil is seen a practically impervious, calcareous, yellow layer of varying thickness. Kunkar is developed in the contact zones of Dharwar schists and the Peninsular Complex.

The country covered by the gneisses consists of loamy and mooram soil often grading into sand.

In the sedimentary formations (*Purana group*) the limestones are capped by black soil whereas the shales weather into ash-coloured loam.

* E. W. Vredenburg :—Consideration regarding the possible relationship between the Charnockites and the Dharwars. Jour. A. S. B., N. S. Vol. XIV, pp. 433-448.

Saline efflorescence and salt works.

Along the junction zones of the Dharwar bands and the Crystalline Complex, saline efflorescence is frequently noted in nullahs. Sometimes, the nullahs running in the body of the Dharwars also indicate such efflorescence. The intimate association of the saline efflorescence to the pink pegmatites and red syenites is easily noticeable in the field. A number of salt works thrive in these saline areas, the salt being generally derived by lixiviating the soluble matter of the saline earth and allowing it to crystallise in pans. Only two instances, one south-east of Kallur and another, south of Kurdi were noted where the saline earth is lixiviated with saline water from brine springs in the vicinity. At other localities the lixiviation is done by water from nullahs and wells.

The saline areas and salt works have been roughly indicated on the map attached. (Plate I).

Economics.

Soil.

The black soil which mantles the broad belt of Dharwar bands accounts for the prosperity of the area covered by the Dharwar rocks. Soil erosion is progressing rapidly exposing kunkar beds (*Vide* photo 14 Plate VI) and if prompt steps are not taken for the bunding of the soils to prevent their annual erosion, the country which now, with sufficient rain is remarkably fertile may before long, become barren.

The seriousness of the situation that would result in the ultimate denudation of the soil, if the present rate of soil erosion is allowed to go unchecked, has been fully discussed and measures to prevent soil erosion in Raichur area have been suggested with illustrated block diagrams in the Journal of Hyderabad Geological Survey, Vol. II, pt. i, pp. 55 to 66. On account of the great economic importance of the subject to the Government and the people in

this district, this question is further referred to in a separate note. (Section B.).

Salt works.

The thick deposits of saline efflorescence noted in the area may justify greater encouragement being given to the salt industry which can provide occupation for a much larger number of men in the district.

A number of salt works already exist along the junction zone of the Dharwar formations and the Peninsular Crystalline Complex. The position of most of these salt works are indicated on the saline map. (Plate I). In an area like the Raichur district which on account of insecure rainfall, is subjected to chronic famine conditions the manufacture of salt on a larger scale as a cottage industry has vast potentialities and, with regulated help from the Government, can afford employment to a much larger number of people than are at present engaged in the industry. The Geological Survey Department conducted some special experiments for the economic utilisation of these sources as an organised cottage industry. (*Vide* Jour. Hyd. Geol., Surv. Vol. II., pt. i, pp. 179-216). Most of the requisites for the plant are obtainable locally. The practicability of this method for the increased production of salts and the economic utilisations of even weak brines deserve serious consideration with a view to give organised Government aid to this dying industry.

The analyses of typical saline waters from the eastern parts of the Raichur Do-ab, are given in the table on page 78. The existence of large areas where both sodium carbonate and sodium sulphate can be obtained by lixiviation should be an inducement to encourage a detailed examination into the possibilities of a glass and ceramic industry in the district.

Glass and ceramics.

The possibilities of white quartz veins and the utilisation of feldspar from pegmatite veins (both of which abound in the area) for glass and ceramic industries deserve careful examination.

A number of minor veins of quartz and some prominent fs have been noted in the area covered under report. me of the more important of them may be instanced as :urring at Sultanpur, Jagarkal—Mallapur, near Yeram-, Bayalmerchaid, between Valkamdinne and Bichala, daknur and Induvasi. In most of these places, it is ssible to get white quartz free from iron and other impu-es. On account of the nearness of the Railway line to 'eral of these localities, transport charges may not be :y much from the quarries to the rail-heads. With the reasing industrialisation of the Hyderabad State, these fs are sure to acquire an economic value.

The existence of vast dumps of crushed and powdered ırtz in proximity to the abandoned gold mines, parti-arly near Hutti, may furnish ready raw material for the ss industry. The availability of the necessary salts for : purpose in close proximity to these dumps, specially Guddinhal and Surjapur areas is a further inducement to ısider the industrial possibility of a glass industry near .tti. A good road communication already exists between .tti and the rail-head, Raichur, a distance of about 50 .es.

Good quantity of potash feldspar for the ceramic in-stry may be obtained from the neighbourhood of Parti-li, Turkandoddi, Matmari and other localities further st. These feldspars form extensive sheets over the .nodiorites and with hand picking, it would be possible, separate them out from the occasional quartz admixtures. ese are within a radius of 5 miles from the Matmari ilway Station.

'opper.

Some old workings reported by Knight in Gadwal Samasthan have been identified by the Special Officer as old copper workings during his inspection of the area. ough surface indications are not encouraging with ard to their richness or extent, the possibility of detailed ıspecting disclosing workable ore should not be lost ht of. The green encrustations of copper in the aplite

veins west of Timmapur at the junction of Dharwars and the Peninsular Complex require further scrutiny.

Iron.

Lateritic segregations of ferruginous minerals in a nullah bend were noted west of Rajavoli;[1] but as the surface is covered by a thick mantle of black soil, it has not been possible to define their source and extent. The sample assays 63·57 per cent. of iron :—

Gold.

The old workings at Hunkuni have already been described in Vol. II, pt. i, p., 91 of the Journal. Made-ground between Shankeshwar and Tippapur deserted village with strewn light blue and slaty quartz amidst suggestive depressions in the body of the schist band is a possible indication of old gold workings. Extensive panning from the blue quartz collected from the area gave very doubtful and faint indications of gold. The presence of saucer-shaped depressions on the flanks of Gabur hill and the large number of grinding stones (*Mullackers*) in the villages around, lend strength to the surmise that some old gold workings masked by soil may exist in this part of the Dharwar band.

In this connection the following note by the Special Officer may be added.

" It has been clearly explained in the previous part of this paper the difficulties that have been experienced, owing to the vast spread of black cotton-soil, of even demarcating the boundaries of the newly discovered Dharwar band. At present no old workings have been noted, and if these exist (and there is no reason why they should not) they must during the course of centuries have been levelled off, partially by the migratory nature of the soil, which has been accentuated by the efforts of the ryot to obtain a level surface for his cultivation. If old workings exist on these bands the only hope of locating them will be by an aerial survey, preferably made when the young crops are springing up with the Khariff or Rabi crop. The above remarks

1. Rajavoli (B.3 ; 1.9).

ıply to all the area of gold bearing Dharwar rocks, and until .ch an aerial survey is made, the economic possibilities ˙ the Raichur District will never be fully known."

Diamonds.

Banaganapally conglomerates are known to be diamondiferous and deserve detailed investigation. Whether modern machinery can be devised to deal cheaply with this material, without ushing the gems, is a subject worth consideration.

Building Stones.

In Vol. II, pt. i, pp. 98-99 of the Journal, a comprehensive note on building stones in Raichur District has been given. So, only a brief mention ˙ this subject may here be made.

Good building materials are obtained from the granooritic hills and the groups of gneissic hills in the eastern ɔrtion of the Raichur Do-ab.

The jointed gneisses often break into blocks of large mensions and they are of great value as building materials ır flooring, walls and even roofing. On a very small ale, the stone wadder is seen separating out gneissic slabs r local use by fire setting in such favoured areas. In a eeless district like Raichur where timber of any kind is re and consequently costly, the use of such slabs of granid gneisses has a great economic utility. The Government while granting license for quarrying broken metal ır roads may be well advised to conserve such areas which e capable of yielding big blocks for building construction. his step seems to be of primary importance to a district hich has great scope for industrial development in the :ar future.

Limestones and slates in Alampur taluq are also used blocks and slabs for buildings purposes.

We must again draw attention to the beautiful decoraᴦe rocks of the district—wonderfully rose-red coloured enite veined with green pistacite, some slabs of the granid gneiss streaked pink and white, sometimes with browsh hornblende bands,—all of which if polished, would ake beautiful dados to decorate some Hall or Council ıamber. The above rocks together with green horn-

blende schist, wavy streaked, brown banded hæmatite schist, conglomerates composed of highly coloured pebbles of cornellian agate jasper and chalcedony, if cut into tiles would make a marvellously decorative mosaic floor.

ROAD MATERIALS.

In a district like Raichur where communications are still inadequate and a large programme of road construction is in progress, a note on the road materials is of practical utility. Suitable stone for soling and metalling, clay, sand, gravel, lime, slab stones, and water for consolidation, are obviously the essential materials required for road making. It is of fundamental importance that the lay-out of a road should be within easy reach of these materials. Examination of an area with regard to the materials has therefore to be directed with reference to their (*a*) quality (*b*) quantity and (*c*) accessibility.

Clay and Sand.

Over large areas of the Raichur Do-ab, thick layers of black cotton-soil overlie the subsoil. The subsoil is also frequently a calcareous clayey layer. In its untreated state, it is an unsuitable material for any process in road construction. If spread on a road the clay or calcareous clay, with the slightest rain, becomes sticky and slippery and a positive danger to motoring, and when dry, it cracks. In several countries it is found advantageous to mix sand with clay. If clay is used to fill voids between sand grains, good results are obtained. The ingredients have to be mixed properly. Such a mixture affords good drainage condition and water-logging is hardly induced. A mixture of 30 per cent. of clay and 70 per cent. of sand has been found to constitute a convenient proportion. Numerous nullahs cut through the whole area and it may be easy to obtain the required quantity of sand from these nullahs. This suggestion might be tried in those areas where good quantity of mooram is not available.

Apart from the utility of sand for the purpose mentioned above, it is extensively and advantageously used with mooram for blindage of metal roads. It is most essential

for making lime or cement mortar. For this purpose sands from saline areas are found to be useless. An examination of areas where sand can be obtained free from saline ingredients then becomes necessary.

Gravel and Mooram.

Gravel is a general name applied to the unconsolidated material which will not pass 4 mesh sieve. Gravel deposits have to be examined with reference to available tonnage, extent, shape, lithological characters, texture, depth of weathering and approximate quantity of clay, sand, and organic matter in the deposits. In some favourably situated localities such as regions in proximity to the northern bank of the Tungabhadra and southern bank of the Kistna rivers, good deposits of gravel and mooram are found in abundance. Round about Mudgal, Gangawati and Kavital, also in areas adjoining Kalmali, Murharpur and Venkatapur, good quantity of mooram is noted in several places sometimes up to 40′ or 50′ in depth, underlying the soil cap. Deposits can be located in that area which are free from excessive calcareous clayey matter. East of the Railway line gravel and mooram deposits are easily obtained.

In some areas of the Dharwar formations, particularly where the black cotton-soil mantle is thick, the sub-soil is generally calcareous and clayey. This clayey material when dry breaks up into gravelly deposits. During wet weather this becomes sticky and water-logged and roads with a spread of this material become almost impassable. In Raichur District such calcareous clayey beds are found adjacent to the main roads over long distances. This is extensively used during road construction. If it becomes imperative to use this material, the advisability of mixing it with coarse sand may be considered if more satisfactory results are desired. Whenever possible such areas should be avoided even if it makes the total length of the road longer by several miles, as proper maintenance without good mooram is impossible.

Gravel of good quality in appreciable quantities is

often obtained from nullahs and streams all over the area and a careful survey will reveal favourable spots along the nullahs where gravel is concentrated.

Material for Soling and broken metal.

Igneous, metamorphic or sedimentary rocks are well suited for road construction. In the Raichur District all the three types are obtainable.

Rocks may consist of primary and secondary minerals. Quartz, feldspar, pyroxenes, amphiboles, micas, garnets and olivine are generally primary, the secondary minerals consist usually of chlorite, kaolinite, sericite, limonite, serpentine and epidote. Small amount of secondary minerals in the rock increase its binding power. Excessive quantities of these may have just the opposite effect.

The weathering qualities of the rocks are important factors in the choice of road materials. Hard gneissic rocks with tightly interlocking grains are stronger and better than any other type as road material, specially if small quantities of secondary minerals are present, which may add to their cementing value. Easily soluble rocks such as limestones are not good for road construction. Strongly foliated metamorphic rocks such as schists are not suitable as they wear out easily due to their softness and fissile structure.

In examining outcrops, or hills for the suitability of road material, it is necessary to know the kind of rock, (*i.e.* igneous, metamorphic or sedimentary), texture, composition, cleavage, *etc.* In the Raichur Do-ab the following rock types are met with.

Localities :—Vast quantities of hornblende and chlorite schists are available in the main bands of Maski and Kushtagi areas. Several outcrops of these rocks also occur between the Kistna (North of Deodrug) and Kalmali, between Bayalmerchaid and Bichala, near Gudavaram, Udamgal, Mirzapur, Talmari, Idgaunpalli and in parts of the Gadwal band. These are suited for the final stages of top dressing on account of their cementing properties.

(*a*) Hornblende and Chlorite Schists.

(*b*) Granodiorites.

A number of hills and minor outcrops of granodiorites in the eastern portion of the Raichur Do-ab afford good road material. The hills around Kallur, Kalmali, Nilgal and Ganekal are easily accessible. These rocks are highly jointed and on this account, boulders of smaller dimensions for soling and top dressing can be easily obtained. Besides these, all along the Dharwar bands minor outcrops of such rocks occur in appreciable extent. Such outcrops are available around Amrapur, Hanumapur, Venkatapur, Fatyapur, Partipalli, Turkandoddi, Upanal, Gundavalli, Tottinenidoddi, Sindhnuru, Kutaknur and in some localities flanking the main Maski and Gadwal bands. It is possible that these outcrops extend in depth.

(*c*) Granitoid Gneiss.

In the Raichur Do-ab, granitoid gneisses occur as hills in several localities. Groups of hills in the neighbourhood of Manvi, Mudgal, Gangawati, Anegundi, Ginigera, Kavital, Lingsugur, Gurgunta, Deodrug, Maski, Nirmanvi, Rubenkallur, Kurvi, Gorkal, Hardigudda, Sirvar, Maladkal, Gabur, Ramdrug, Kakargal, Raichur, Malliabad all afford excellent road material. The constituent minerals are quartz and feldspar, accessory hornblende and mica with secondary epidote. Besides affording excellent material for road metal, in several localities these granitoid rocks on account of the jointing can be split to supply slabs of good dimensions. In most of these hills the stone waddar is seen active recovering such slabs by fire-setting. The utility of these slabs broken into small blocks for paved-road construction is worth serious investigation, specially as good-sized blocks in appreciable quantities can be obtained in all the places enumerated above. In the recent Roads Conference organised by the Government of India and the Indian States, the utility of the paved-roads were

* Note by Special Officer.

Granitoid gneiss is a term which covers an enormous number of varieties of metamorphic rocks, generally termed granites by the P.W.D. Engineer. Among these rocks some make ideal road material while others—generally those classified as binary gneisses

fully recognised and it was announced that experimental paved-roads have proved a success in the Mysore State. The size of the blocks to be used is variable according to circumstances. For first class pavement, gneissic blocks 8″ to 12″ long, 8″ to 5″ wide, and 7″ to 8″ deep are found suitable. For culverts and bridges the economic utility of slabs and beams of granitoid gneisses in the place of cement concrete construction is worth investigation. The ease and the abundance with which the granitoid gneissic materials can be obtained within reach of any part of the district has already been emphasised.

The excellence of the granites of the Raichur District with regard to the physical properties to stand heavy construction has been recognised after vigorous comparative tests.

(*d*) Dolerite Dykes.

In the Geological map, the distribution of the dykes in the area under report is indicated by black lines. Some of the dykes are quite long and wide. On account of the weathering of the dykes into blocks and rounded boulders suitable material can be obtained for road construction. Due to their toughness they are harder to break, but the great abrasive and cementing properties of these rocks make their use cheaper in the long run. In practice they are used widely all over the world as soling stones and road metal. This rock is recognised to be one of the best for the wear and tear of heavy traffic.

crumble to sand as can be seen between Jalhalli and Deodrug, round about Koratgi, between Manvi, Sadapur and the Tungabhadra river to the south. Until more laboratory tests are carried out regarding the physical qualities of these rocks, no accurate information can be given. It is particularly requested that the Chief Engineer would instruct his subordinates when they are making road reconaissances to send samples of rock met along the proposed route when special attention will be given to them and an early report given as to their suitability or otherwise for road material.

Numerous quartz veins and reefs occur in the district. These do not constitute good road material on account of their low cementing value, though they have good wearing qualities and toughness. They are found useful if top dressing of the road is done with stones of good cementing qualities. In this connection attention may be drawn to the utility of hæmatite quartzite which are extensively found in the western parts of the district. The iron contents and chloritic impurities supply the necessary cementing ingredients thus increasing its value as a road material.

(*e.*) Quartz veins, quartzites and Haematite quartzites.

Towards the western boundary of the district near Hanamsagar and the S.E. corner of the Do-ab, in proximity to the confluence of the rivers Kistna and Tungabhadra, sedimentary rocks such as sandstones, limestones and shales have been located. Siliceous shales afford good material for road construction if the traffic is not very heavy. Limestones have good cementing properties and can be used for top dressing of roads with quartzitic sandstone foundation. Since the properties of these three types are more or less complimentary, the compact sandstones, for example, possessing high abrasive properties and limestone and shales characterised by greater cementing values, a judicious combination of these types in the area will be found helpful in the construction of durable roads.

(*f.*) Sandstones, limestones and shales.

Village Water Supply.

The existence of large areas of underground saline water in the Raichur District renders the problem of providing drinkable water to villages most difficult. In the previous numbers of the Journal, the causes of salinity in the district and the distribution of saline areas in the western part of the Do-ab have been discussed at length. In section B of the present

Drinking water for villages.

number, this question has been reviewed again and the details need not be reiterated here. Map I shows the distribution of saline areas in the eastern parts of the Raichur Do-ab. In defining these saline zones, the evidence afforded by existing wells, springs and efflorescence in the nullahs have been utilized. In this area, where villages are scattered and wells in consequence few in number, adequate information could not be obtained to claim absolute accuracy for the boundaries of saline areas demarcated. They are rough approximations but have, so far, proved reliable from the data afforded by the intensive well sinking campaign now in progress in the eastern part of the district by the Well Sinking Department. Attention may be drawn to a few salient points with regard to the distribution of saline areas in the eastern parts of the Do-ab, now under review.

Salinity along river banks and nullahs.

It is generally noted that most of the existing wells in proximity to the Kistna and the Tungabhadra rivers are saline. In Plate I and block diagram Plate VI Photo 13 the cause of the concentration of saline water along river banks has been explained.

In view of the fact of the people preferring river and nullah water for most part of the year wells have been proved to be very little used, except for a month or two in the monsoon season when the water of rivers and nullahs are turbid Even if deep wells tapping subterranean sweet springs were possible and given to the villages in such areas the water would turn saline due to continued disuse and consequently saline matter would gradually concentrate in such wells. Similar causes and conditions account for the salinity of the underground water on the banks of big nullahs. The villages of Ponnuru, Jukuru, Rajavoli, Kataknur, Gundravali along the north bank of the Tungabhadra and Kadlur, Karakal, Atkur along the south bank of the Kistna may be mentioned as instances falling within this category. Other villages on big nullahs where the underground water is saline are indicated in the map.

A reference to the saline map brings out the location of the other saline zones in the area. The geological formations are also indicated in the map. It is seen that saline areas fringe the junction of the Dharwar series and the Peninsular Crystalline Complex. Along these planes of junction zones, pink pegmatites and red syenites are abundantly developed and there seems to be no doubt that the decomposition of these rocks account for part of the salinity of the underground water in such areas. Typical instances of this type of underground saline water are to be found in the villages of Shankeshwar, Timmapur, Hanumapur, Venkatapur, Fatyapur, Ganekal, Nilagal, Hukrani, Matmari Railway Station Hanchinal, Alkur, Gandhalu, Yedaknur, Tottinenidoddi, Manjidi and Yegnur.

Saline water due to pink pegmatites and red syenites.

In Vol. II, pts. i and ii, attention has been drawn to the existence of deep brine wells which were also described by Bruce Foote.* The widespread existence of brine is borne out by the analyses given in Table I page 78. The waters from wells give percentages of chlorides far in excess of any amount that could be derived from decomposition of any known rocks in the area. The existence of such deep-seated brine has been questioned and the underground salinity attributed solely to decomposion of the soil and it has been claimed that irrigation with sufficient drainage canals will remove these salts as has happened under entirely different geological conditions in the Kurnool District. We wish here to record strongly our considered opinion based on careful observations that considering the local conditions of the area, no irrigation even with heavy pumping from wells can ever *entirely* eradicate the salts derived from these underground saline springs.

Generally, the country covered by the grey or pink granitoid gneisses affords drinkable water.

Grey and pink granitoid gneissic country.

* Mem. G. S. I. Vol. XII p. 253.

The Vindhyan rocks which have been demarcated in the south-eastern portion of the Do-ab, in proximity to the confluence of the Tungabhadra and the Kristna afford drinkable water and no saline areas have been noted in the area covered by these formations.

Sedimentary formations.

In practice, it has been found impossible to give villages wells the quality of whose water satisfy the requirements of *potability* according to western standards. If the high standard defined as *potable* have to be strictly adhered to, it might be fairly said that the whole of the Raichur District would have to be evacuated. The standard of drinkable water is determined in the district according to local conditions, and the Well Sinking Department takes every care that the best available water in the area is given for the village water supply.

"Potable water."

The existence of drinkable water in the sands of nullahs in the saline area divided from the underground saline water by impervious clay beds is being taken advantage of and sand traps and the sub-surface dams as advocated in Vol. II, pt. ii, are finding wider use in saline areas. In several places the above contrivances have proved very successful and afforded relief and benefit to the suffering villagers.

Use of sand traps.

Chemical analyses of some type saline water samples are given in Table I.

Archæological Finds.

During the course of the field work 1343 F. in the area under report some interesting pre-historic relics such as Ash Mounds, Stone Circled Graves, and a few stone implements were noted and their locations have all been indicated on the Geological Map No. 2.

1. An ash mound occurs on the Manvi hill (Lat. 15o 59′ 30″ and Long. 77o 2′15″) about 50′ × 50′ square from which samples of ash and pot shreds and broken bits of rubbing stones were collected. The material corresponds in composition with the ash mounds of Wandalli and Machnur.

Ash Mounds.

A very fine-grained narrow dyke about 1 to 3 ft. in width cuts through the Manvi hill in broken continuity and in places it presents a pitted appearance. Tradition connects the ash mound to this chilled dyke. The narrow dyke is said to represent the poison omitted by the serpent Thaksha on his way to bite Parikhshit Rajah according to a curse chanted by a Rishi.* The pittings in the dyke are supposed to represent the footprint of the mongoose which tried to prevent the progress of the serpent. The ash mound is said to be the remains of a Yagna (*Sacrifice*) which was performed by Janamejaya, son of Parikshit Rajah, to exterminate the serpents to avenge the death of his father from snake-bite.

*Prince Parikshit, son of King of Manvi, went out hunting and being thirsty, accosted a sage doing Tapasya to be directed to a spot where he could get water. Being in trance, the sage could not reply the prince. Enraged at this, the impetuous prince took a dead snake that was lying near by and put it round the sage's neck and went away. Sometime later, the sage's son came there and finding his father thus insulted

TABLE I.

Results of the Analysis * of Brine Samples from the Eastern Portion of the Raichur Do-ab.

Serial No.	Locality	Total solids in 100 cc. sample	Specific Gravity	NaCl	Na_2SO_4	Caronates mostly Na_2CO_4	$CaSO_4$	$CaCl_2$	$MgSO_4$	$MgCl_2$	Nitrates	Iron and Alumina	Total
1	HANUMAPUR ..	1.3428	1009.0	31.14	..	..	27.62	2.01	..	17.24	21.90	..	100.00
2	Well at Salt works—KURDI ..	1.5718	1011.0	54.73	..	1.44	17.05	..	8.68	7.07	10.37	0.66	100.00
3	Saline spring near Salt work—KURDI ..	1.3278	1008.0	51.04	..	..	19.20	8.01	..	7.86	13.80	..	100.00
4	FATYAPUR ..	0.3100	1001.9	33.95	18.47	18.26	11.90	..	15.28	..	2.14	..	100.00
5	KALLUR ..	0.6908	1003.7	8.28	..	7.39	13.98	10.30	..	14.81	45.24	..	100.00
6	BAMANHAL ..	0.5208	1003.2	23.42	..	6.61	17.72	..	0.47	15.98	35.80	..	100.00
7	BEVANUR ..	0.5116	1005.0	40.70	3.86	13.23	11.77	..	19.05	..	1.79	..	100.00
8	GANEKAL ..	0.6540	1004.0	2.47	..	10.35	10.97	23.14	..	10.17	42.90	..	100.00
9	MASJIDPUR ..	0.3908	1003.0	38.90	1.47	14.53	35.29	..	7.85	..	1.96	..	100.00
10	GUNDAWARAM ..	0.6212	1005.3	51.88	..	12.70	1.02	..	18.31	1.82	14.27	..	100.00
11	ALKUR	0.5422	1004.7	37.20	22.90	20.72	3.23	..	7.02	..	8.93	..	100.00
12	UDAMGAL ..	0.2102	1000.6	64.75	..	24.88	..	..	5.20	5.17	..	..	100.00
13	MALSHETTIHALLI ..	0.7010	1005.7	32.94	7.53	9.68	17.60	..	21.43	..	8.48	2.34	100.00
14	MATMARI Ry. Station.	0.3514	1003.0	23.70	23.08	25.34	9.67	..	10.47	..	7.74	..	100.00
15	VALKAMDINNE ..	0.2540	1002.2	14.84	..	21.70	14.97	10.68	..	15.15	22.48	..	100.00
16	RAJAVOLI ..	0.3690	1001.8	21.84	..	12.21	12.24	..	1.45	12.53	39.73	..	100.00
17	JUKURU ..	0.1432	1000.6	9.62	..	27.82	14.60	..	0.05	1.07	46.84	..	100.00
18	GANDHALU ..	0.1878	1001.1	11.49	..	36.12	8.83	13.88	..	1.54	28.14	..	100.00
19	MIRZAPUR ..	0.0988	1000.3	17.12	..	42.92	7.35	3.51	..	0.52	28.58	..	100.00
20	TOTTINENIDODDI ..	0.1620	1001.5	25.15	20.83	41.88	3.00	..	2.93	..	6.21	..	100.00
21	UTTANUR ..	0.1428	1000.8	24.57	..	47.51	2.28	1.48	..	5.40	18.76	..	100.00
22	SHAKAPUR ..	0.3632	1003.0	14.84	..	30.35	6.74	3.22	..	25.14	19.71	..	100.00
23	EKLASPUR ..	0.2320	1002.2	35.11	..	27.41	13.37	1.73	..	7.97	4.41	..	100.00
24	MASIDODDI ..	0.1040	1001.2	6.16	..	16.19	2.81	..	4.86	16.72	53.26	..	100.00
25	JAMBALDINNE ..	0.1268	1001.2	6.40	..	61.52	5.15	7.06	..	..	19.87	..	100.00

2. Four ash mounds have been located east of the G.I.P. Railway line, Raichur Taluq.

(*a*) An ash mound to the north of the track between Talmari and Kutukunuru about a mile west of the latter village may be noted. (Long. 70° 31′ 20″, Lat. 15° 56′ 15″). This mound is oval in shape, similar in composition to those observed in Gaudur and Machnur, Gurgunta Samasthan, about 280′ by 250′ and 20′ high. A few broken pounding stones were picked up from the edge of the mound.

(*b*) Two ash mounds occur about 2 furlongs to the south-west of Manchanpalli (Long. 77° 36′ 40″, Lat. 16° 3′ 40″), on both the sides of the track between Mirdoddi and Manchanpalli. Both these mounds have practically been removed by the villagers and only a small residue may now be seen. They are about 100′ by 50′ in area, oval in shape and about 5′ to 6′ in height.

(*c*) Idgaunpalli Ash Mound (Long. 77° 38′, Lat. 16° 0′ 40″). This is similar in size to the Kutukuhnuru Mound, oval in shape about 250′ by 200 and about 15′ in height and is seen about 2 miles to the west of Idgaunpalli to the north of the track between Idgaunpalli and Ij.

chanted a curse that the person who was responsible for this misdeed would meet his end by snake bite. The sage just then opened his eyes and realising that the thoughtlessness of the prince should not be so seriously treated, but powerless at the same time to revoke the curse, warned the prince to take necessary precautions. Parikshit took refuge in an island castle and kept a vigilant watch.

Taksha the venomous serpent proceeded to fulfil the decree of the curse. On its way the faithful mongoose of the prince chased the serpent, but in vain. A very capable physician who proved his prowess in reviving people bitten by the most venomous snakes was bribed by Taksha to give up his projected help to the prince.

On the decreed day, the serpent contrived to give the prince the fatal bite.

The villagers say that this ash mound is the original site where old shepherds used to pound their cattle and where fire was burnt in the night to keep off wild animals.

Stone Circles.

Many stone circles are noted in the hill tracts towards the north of the area under report, east of Railway line, near the south bank of the Kistna river, mostly in the Gadwal Samasthan, where a network of doleritic dykes is found.

Another group is particularly noted north of the Tungabhadra river and west of the Railway line in Manvi Taluq in the vicinity of a group of parallel doleritic dykes.

The following localities may be mentioned.

(1) About four to five stone circles were noticed near Idulpalli village. (Long :—77° 44′ 33″, Lat :—16° 5′ 42″).

(2) About a furlong away from the south bank of the Kistna river about three stone circles were noticed. (Long :—77° 40′ 49″, Lat :— 16°19′ 51″).

(3) There are more than 15 stone circles within about a mile to the north-north-east of Upri village. (Long :—77° 40′ 14″, Lat :—16° 19′ 41″).

(4) More than 20 stone circles were noticed within about a mile north of Chinna Chintadura (Long :—77° 42′ 5″,)., (Lat :—16° 19′ 18″)

(5) Within about half a mile to the north of Vampalli village a few stone circles were observed. (Long :—77° 40′ 57″, Lat:— 16° 18′ 41″).

(6) About 15 stone circles were noticed within about half a mile to the west-north-west of Pedda Pahad village. (Long :—77° 44′ 0″, Lat :—16° 17′ 0″).

(7) More than 12 stone circles were noticed about a mile to the east of Palcherla village. (Long :—77° 44′ 0″, Lat :—16° 15′ 21″).

(8) About 7 stone circles were observed within about a mile to north-east of Devampalli. (Long :— 77° 41′ 8″, Lat :— 16° 14′ 33″).

(9) To the east of Darur, about two miles, just to the south of the track Darur-Gadwal, there are more than 30 stone circles, all well defined. (Long :—77° 43′ 40″, Lat :—16° 14′ 7″).

(10) About 20 stone circles were located to the south of the track Latipur-Gadwal. (Long :— 77° 50′ 33″, Lat :—16° 13′ 4″).

(11) One large group of stone circles was observed between Mailguda and Patapalem. (Long. 77° 36′ 35″, Lat :—16° 15′ 30″).

(12) Another group of stone circles may be noted between Patapalem and Natampahad. (Long:— 77° 36′ 25″, Lat :—16° 18′ 10″).

(13) A group of stone circles 1½ miles N.N.W. of Duddal. (Long :—77° 7′ 30″, Lat :—15° 58′ 30″).

14) A group of stone circles 2 miles N.E. of Sadapur. (Long :—77° 9′, Lat :—16° 0′).

(15) A very big group of stone circles 1½ miles N. of Harnahalli. (Long :—77° 9′ 30″, Lat :—15° 59′).

(16) A big group of stone circles 1½ miles E.N.E. of Rajalbanda. (Long :— 77° 12′, Lat :—15° 58′).

(17) A big group of stone circles 1 mile west of Jukuru. (Long :—77° 12′ 30″, Lat :— 15° 58′).

(18) A group of stone circles 1 mile N.N.W. of Kamalhatti. (Long :— 77° 14′, Lat :—16° 0′).

(19) A group of stone circles 1 mile N.W. of Valkamdinne. (Long :— 77° 14′ 30″) (Lat :— 15° 59′ 30″)

(20) A very big group of stone circles just north of Kataknur. (Long :—77° 16′ 30″,) (Lat :—15° 58′.)

(21) A group of stone circles 1 mile east of Kataknur. (Long :—77° 17′ 00″,) (Lat :—15° 57′ 45″.)

(22) A group of stone circles north of Gutbichala hill (Long :—77° 18′ 30″,) (Lat :—15° 59′ 30″)

(23) A group of stone circles, from which most of the stones have been removed is seen just north of Timapur 2 miles S.S.E. of Girijapuram (near Kistna River). (Long :—77° 16′ 15″,) (Lat :—16° 22′ 30″)

Stone alignments.

About a mile and a half S.S.E. of Hardigudda is a hillock of quartz, (Long :— 77° 2′), (Lat :—16° 0′ 30″), and in proximity to this are noted a number of dislodged rectangular slabs of granitoid gneiss most of which are now used as boundary stones of fields. Some of the slabs which are more massive may still be seen in their original sites. The site was visited by the Special Officer who identified the relics as Stone Alignments.

Stone Implements.

Some stray pieces of stone artifacts were picked up from near Maladkal and south of Gabur. They are also found associated with some of the circles.

A fine-grained dyke west of Alganpalli (Long :—77° 42′ 16″, Lat :—16° 10′ 42″) running E.S.E. to east, is found to be strewn over almost all along its length with fine chips and fragments of the same rock, suggesting a pre-historic manufactory for stone implements.

S. K. Mukherjee
L. S. Krishna Murthy
C. Mahadevan
H. S. Krishna Murthy

SECTION B.

A note on the Salinity in Relation to Soil and Geology in Raichur District by Captain Leonard Munn, O.B.E., (Mil.), M.E.

Introduction.

In the Journal of the Hyderabad Geological Survey Vol. II, pts. i and ii, the problem of salinity in the western portion of Raichur District in relation to soil and the geology was discussed at length. The geological survey of the eastern portion of the Raichur Do-ab which was completed during the last field season disclosed a big band of Dharwars previously unreported, and several smaller patches covered by vast spreads of black cotton-soil. Saline areas of considerable extent have been demarcated in the area showing interesting relationship to the geology and the soil. On account of the great importance of the subject, it is thought that a note in non-technical language, on the soil and salinity may be found to be of practical utility to the Government and the general public.

Kinds of Salinity.

Salinity in the area may be classified (1) superficial, (2) deep-seated. On account of the intimate association of superficial salinity with the soil, a digression on the subject of soils in the area may not be irrelevant.

Main soil types.

In the Raichur Do-ab two main kinds of soil are met with. The black cotton-soil generally caps the Dharwar formations and regions in proximity to the Dharwar series. The red loamy soil is characteristic of the gneissic area. The classification and origin of the various types of soil in the Do-ab have been discussed in Vol. II, pt. i of the Journal (pp. 55-56)

Black cotton-soil.

Without again going into the details, it may be pointed-out that the location of the newly discovered band of Dharwars extending from the Kistna to the Tungabhadra in the eastern part of the Do-ab suggests that to a great extent, the

black cotton-soil is of local origin and the deep migration from a distance need not be called upon to account for its existence. The cotton-soil country which roughly coincides with the area covered by the Dharwar rocks is seen to constitute a high undulating plateau separated by systems of nullahs. The cotton-soil varies in thickness; 5 feet or 6 feet may be taken as an average, but sometimes, though rarely, it attains a depth of 20 feet or more. This soil is separated from the underlying rock by a layer of a semi-impervious calcareous clay to which reference will again be made.

It is now widely recognised that the individual particles of the black soil are of colloidal dimensions. Harrison and Sivan* have shown that the black colour of the soil is not so much due to organic matter, or iron, as due to the finest division of the constituent particles. This feature, together with the fact that the soil forms undulating plateau explains why it is being rapidly eroded away by rain water during the wet months and by wind in the dry weather. This later form of erosion in this treeless wind swept area is a greater factor than is generally supposed. The author has already strongly advocated a policy of replantation for other reasons, and if this was undertaken both forms of erosion would be considerably reduced. The rate of erosion of the soil is much greater than the rate of formation and if adequate steps are not taken to device some means, such as field bunding, to prevent this erosion, what is now a fertile land may ere long be converted into an uncultivable waste. Attention to this alarming state has been drawn in the previous numbers of the Journal and steps suggested how to combat the danger.

Semi-impervious layer underlying the black cotton-soil.

During the course of well sinking, and from other evidence, all over the black cotton-soil area, just below the soil cover, an impervious layer of calcareous clay has been found to exist. This calcareous clayey layer owes its origin to the semi-arid conditions due to

*Harrison and Sivan : Agri. Res. Inst. (Pusa) Chem. Ser. Vol. II No. 5.

intermittent rainfall and lack of proper underground drainage in the area. The scanty and uncertain rains carry salts and other matter from the black cotton-soil, mostly in solution, but partly in suspension, to lower levels during their downward course and deposit them to add annually to the thickness of the underlying semi-impervious calcareous layer. In course of time, this layer assumes an appreciable thickness and acts as a barrier between the underlying rock and the overlying soil. This clayey layer when exposed by total erosion of the cotton-soil is uncultivable owing to the existence of noxious salts and this total erosion is often observed specially on the slopes towards nullahs, though other large areas are frequently to be found. In plate VI photo 14 is seen such an erosion of the black cotton-soil exposing the yellowish calcareous layer.

With a rainfall of 20 to 30 inches if distributed, at the proper time, the black cotton-soil area, with its underlying impervious layer, yields the most wonderful crops. The black cotton-soil, has a high power of imbibition of water. Most of the rain water is held in the interstices between the minute particles of the soil. Added to this, the underlying calcareous clay acts as an impervious barrier and retards the downward seepage of the rain-water. It seems as if an equilibrium has been established in the black cotton-soil area between the physical characters of the soil and sub-soil and the meteorological conditions.

Red Soil.

The red and grey loamy soil has shown to be characteristic of gneissic countries, though of course, it has to be emphasised that black cotton-soil can be derived from hornblende gneisses also, and under certain conditions red loamy soil from the Dharwar rocks.

However, viewed regionally, the red loamy soil roughly corresponds with areas of the rocks of the Peninsular Crystalline Complex in the eastern portion of the Raichur Do-ab. The soil particles here are considerably coarser than those of the black cotton-soil and in consequence have

a higher porosity as well as a high specific yield. These are incapable of retaining moisture for any length of time and require artificial irrigation if they are asked to support intensive cultivation.

An interesting field observation though only local may here be mentioned. It is often found, specially near Manvi, that black cotton-soil in a few places sometimes grades into red loamy soil but that more frequently, when erosion removes both the black cotton-soil and the calcareous layer, only rocky outcrops are exposed. This seems to suggest that the impervious calcareous layer underlying the black cotton-soil has functioned as a protective blanket, preventing further effects of weathering to extend below that layer. When denudation removes both the black cotton-soil and the underlying impervious clay, exposing the undecomposed rock, a great deal of time must elapse before the agencies of weathering break down and disintegrate this rock into soil. In such an area, black cotton-soil, calcareous clay, rocky outcrops and red loamy soil are seen adjacent to one another. The evidence seems to suggest the following cycle of events.

(*a*) Erosion of black cotton-soil exposing calcareous clay beds.
(*b*) Erosion of calcareous beds exposing nearly undecomposed rocky outcrops.
(*c*) Rocky outcrops subjected to agencies of weathering.
(*d*) Formation of red soil as a result of the above.
(*e*) From field observations the possibility of red soil breaking into collodial dimensions and forming black cotton-soil again can be conceded and this stage completes the cycle.

Several scattered localities in the neighbourhood of Nirmanvi and Manvi and between Gabur and Raichur exemplify this cycle.

SUPERFICIAL OR SOIL SALINITY

In the eastern portion of the Raichur Do-ab a number

In black cotton-soil. of salt works exist, situated mostly

on balck cotton-soil in proximity to the junction of Dharwar series and the Peninsular Crystalline Complex. The position of these salt works are indicated on the appended saline map. This map also gives the distribution of saline areas in the eastern portion of the Raichur District. Along the slopes of the undulating black cotton-soil country, and more especially in the nullahs, saline efflorescence is frequently observed. From a detailed investigation of the nature and causes of this salinity, the Geological Survey Department have shown that the black cotton-soil in itself contains sufficient ingredients to account for the formation of most of the salts, especially calcium carbonate, sodium carbonate, calcium sulphate and sodium sulphate. These salts being less soluble than the chlorides have been precipitated at higher levels, the chlorides being more soluble are taken down into solution either vertically, or more frequently seep down towards the nullahs. Thus local concentration of the salts is effected where topographic conditions are favourable.

In block diagram (Plate VI photo 13) the distribution of this superficial salinity is indicated in dotted patches and is marked B. Slopes of the black cotton-soil plateau and banks of nullahs and rivers (which constitutes the lowest elevations, and towards which rain water carries the soluble salts) show surface salinity in large proportions.

Concentration along main river systems

With seepage of superficial salinity towards the minor nullahs, naturally a greater seepage is ever going on towards the main river systems *viz.* the Kistna and Tungabhadra rivers, and the Well Sinking Department have only in a few cases been able to find sweet water to supply drinking water wells to the many villages that line the banks of these two rivers. Plate VI is a photo of an Uppar* girl scraping saline efflorescence from the sides of the Tungabhadra canal which runs parallel to the river from Rajavoli to Bichala, and is separated from the river by a narrow strip of country not more than about 150 yards

* Uppar, Canarese name for salt workers who may be of any caste.

wide. All along the course of this canal saline efflorescence is found in abundant quantities, constituting the raw material for the manufacture of edible salts. Besides the evidence afforded by wells along the bank of the Tungabhadra and the Kistna rivers which are generally saline, this fact further exemplifies the concentration of saline matter along river banks.

Other causes of surface salinity.

Surface salinity may be also caused where topography favours accumulation of salts from the surrounding country with lack of proper underground drainage.

Salinity in red loamy soil.

In the area covered by red loamy soil, in moist places specially near tanks, efflorescence of sodium carbonate with subordinate quantity of saline ingredients are met with in appreciable quantities. The industrial utility of these and other salts have been indicated in the previous volumes of the Journal.

Deep seated or magmatic salinity.

Deep-seated salinity is due to the structural features and geological formations of the rocks lying under the soil and sub-soil mantle. For a detailed discussion on the subject, the reader is referred to Vol. II, pt. i of the Journal, Hyderabad Geological Survey. Only the general features are dealt with here so as to make the problem intelligible to the lay reader.

In dealing with deep seated or magmatic salinity of an area, it has to be recognised that such conditions are accentuated by the addition of salinity due to superficial causes.

Figure 1 is a section of an area where surface and deep seated salinity operate simultaneously. Superficial salinity concentrates on slopes of the black cotton-soil plateau, and at other depressions due to causes already explained.

In addition to these, the section reveals the deep-seated causes that contribute towards further magmatic salinity due to deep-seated brine. In the section a boss of red syenite and branches of pegmatite veins are shown which underlie the soil mantle giving rise to saline matter during

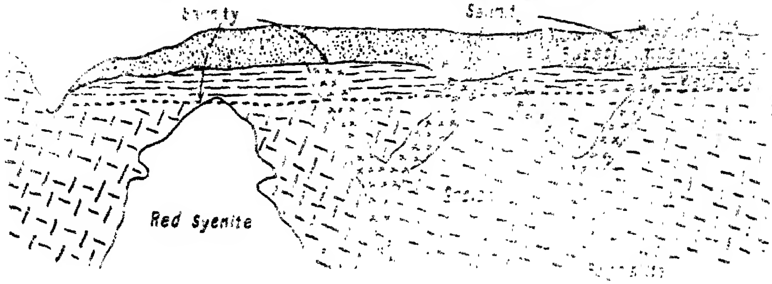


Fig. 1. Section illustrating the nature of superficial and deep-seated salinity.

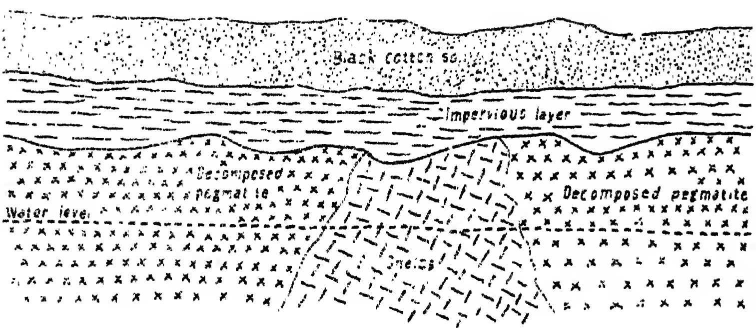


Fig. 2 Section illustrating the effects of light irrigation.

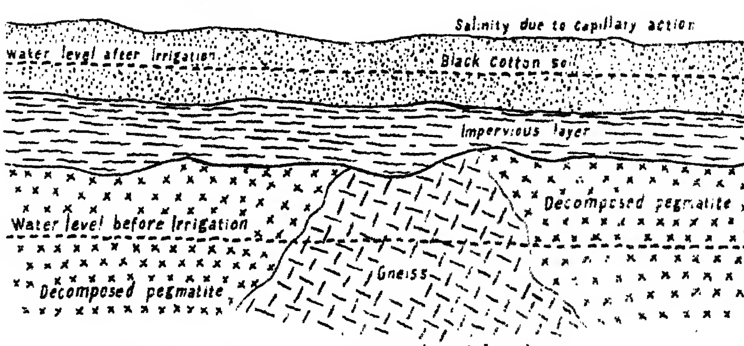


Fig. 3. Section to illustrate results of flooding by heavy irrigation.

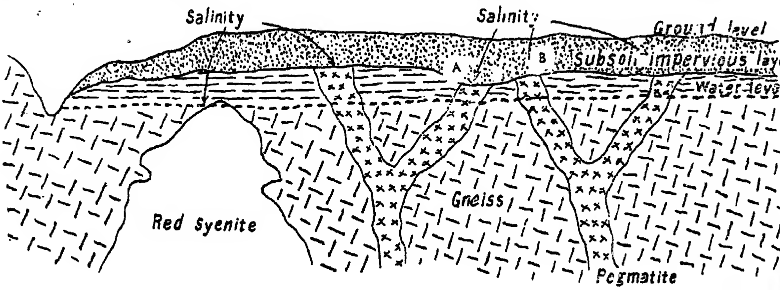


Fig. 1. Section illustrating the nature of superficial and deep-seated salinity.

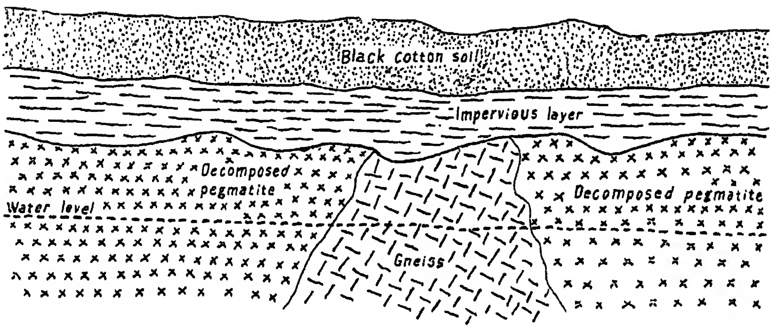


Fig. 2. Section illustrating the effects of light irrigation.

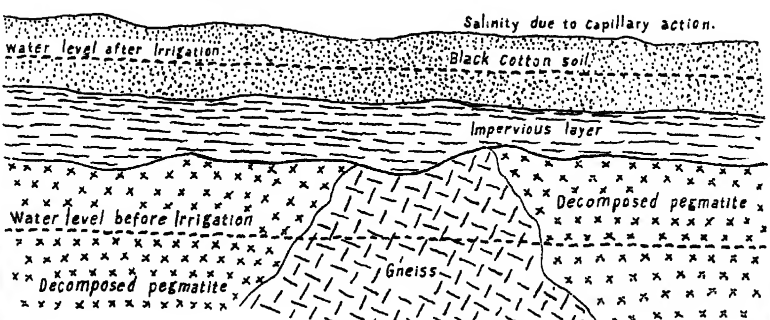


Fig. 3. Section to illustrate results of flooding by heavy irrigation.

the course of decomposition. The underground water table is indicated by broken lines. From a reference to the Journals Vol. II, pts. i and ii, the reader will understand the structural sequence of these rocks and how they contribute towards deep-seated salinity.

In addition to the salts that arise from the decomposition of these rocks, underground deep-seated springs are possible, which contribute towards the total salinity. The existence of such springs can only explain the presence of the high percentages of chlorides which are found in some waters, for these salts are unobtainable in big quantities from the decomposition of any rock, or soil.

Effect of irrigation in an area of superficial salinity.

If irrigation was started in the area where only superficial salinity is encountered, the surface salts might be removed by improving the drainage of the country, either by deep ditches or by localising the salinity in deep wells and pumping out the accumulated saline concentrations into nullahs, or drainage. The block diagram illustrates how this might possibly be accomplished, but the author fully recognises that the expense would be great. C.C. are deep drainage channels which connect to the main river. If irrigation were resorted to local surface salts would be washed down into these channels and thus carried to the river.

If salinity is localised in such a way that owing to the topography the salts could not be removed by solution and gravity, then deep wells would have to be sunk at judiciously selected sites into which the saline matter would be concentrated and then removed by pumping. When dealing with this question of eradication of salts the possibilities of economically extracting the salts by methods fully discussed in Vol. II, pt. i, pp. 137-178 should not be lost sight of.

The *economic feasibility* of these methods as means of controlling effectively the distribution of superficial salinity, if irrigation is introduced, are local problems that will have to be gone into in detail by the engineer and the soil

physicist, but in the opinion of the author it would be far better to make no attempt to start wet cultivation in these areas.

Effect of irrigation in areas of deep-seated salinity and the dangers that may result therefrom.

In the earlier paragraphs it was shown that in areas of deep-seated salinity the effects of superficial salinity accentuated the conditions. The complexity of these conditions preclude the possibility of deep trenching or pumping having any effective control over the eradication of deep-seated salinity. A study of the following sections brings out clearly the nature of deep-seated salinity and the effect of irrigation on these areas.

In figure 2 is shown an exaggerated section in the neighbourhood of A B in fig. 1 after the introduction of light irrigation. Besides the permanent water level which is shown in fig.1., a perched water table is established just above the semi-impervious calcareous layer. Due to capillary action the calcareous matter and other injurious salts are brought up into the black cotton-soil.

In fig. 3, the effect of flooding of an area by heavy irrigation is indicated in section. The perched water table occupies all the space from the bottom of the semi-impervious layer to some depth in the black cotton-soil. Due to capillary action calcareous matter and other salts are taken into the black cotton-soil. The underground saline water table has also risen, replenishing the impervious calcareous layer with saline matter from the deep-seated spring and decomposing pegmatites. The saline matter from deeper layers is reinforced, as it were, into the calcareous layer and ultimately carried into the soil. It is hardly necessary to point out how injudicious flooding of a black cotton-soil area with irrigation may give rise to complications from which it would be difficult or perhaps impossible to extricate. The example in Punjab, where in some areas, heavy irrigation has rendered a once fertile land into uncultivable waste, should serve as a warning to other Governments before irrigation schemes are undertaken.

SECTION C.

A Note on the Bore Well Logs in Aurangabad and Parbhani Districts Discussed in Relation to the Distribution of Underground Water in the Deccan Traps.

BY DR. C. MAHADEVAN. M. A., D. SC., ASST. SUPDT., HYD. GEOL. SURV.

Introduction.

The conclusions arrived at by Captain Leonard Munn,[1] Special Officer in charge, Geological Survey and Well Sinking Departments, regarding the distribution of underground water in the Deccan Traps as a result of his observations during his tour in Gulbarga and Osmanabad Districts were confirmed from detailed field-work in parts of the two districts.[2]

Bore-hole logs of Agricultural Department.

Mr. Collins, Director-General, Commerce and Industries Department, suggested that if this theory was true, an examination of the borewell logs maintained by the boring section of the Agricultural Department in the Deccan Trap area might yield some interesting data in connection with the above studies. The logs maintained by the Boring Section of the Agricultural Department were perused. In the absence of a proper appreciation of the value of the information afforded by the bore-holes, the cores from the bores had not been preserved, and it was further emphasised by the Superintendent in charge of the Boring Section that no absolute reliance could be placed on the data supplied. To obtain the best information under the circumstances, records from the daily reports of the mistries for the deepest bores from some towns in Aurangabad, Parbhani, Nanded and Bider Districts were abstracted.

1. Jour. Hyd. Geol. Sur. Vol. II pt. ii. pp. 89-103 (1934).
2. ibid. pp. 172-195 (1934).

English equivalents for Urdu names.

The English equivalents for the Urdu nomenclature of the boring mistries to describe the various types of the Traps were adopted from either the description of the types, or where possible, from an examination of the actual specimens of the Traps shown in the Boring Superintendent's Office from the samples of the core sent by the mistries.

Observations in the neighbourhood of the Bore-wells.

With data thus collected from the Agricultural Department, the actual places where the wells in question had been bored were visited to see if any further information could be gathered from field observations. In the following paragraphs, some very striking features noted during the course of this enquiry in Aurangabad and Parbhani Districts regarding the distribution of water in the Deccan Traps will be briefly recorded and discussed.

AURANGABAD DISTRICT.

Kannad.

At Kannad about 30 miles N.N.W. of Aurangabad, at about 2070′ mean sea level (M.S.L.) a well was bored near the Munsiffs' Court, of which the following log was maintained.

1′—6′ Dark hard rock.
6′—44′ Exfoliating rock.
44′—75′ Dark compact rock.
75′—93′ Comparatively soft zeolitic rock*.
Water first met with.

93′—102′ Red lithomarge (Crumples when dry).
102′—122′ Compact rock with some zeolites.

It was recorded by the maistry in his diary that strong *springs* were met with in the comparatively soft zeolitic rock layer between 75′—93′. It is hardly necessary to emphasise the significance of the above record or, to point out how the above log confirms the conclusions

* This rock is the aquifer.

arrived at with regard to the distribution of water in the Deccan Trap, namely that the softer decomposed layers are the aquifers. An Isler core drill was used for this boring and representative samples examined from the various depths bear out the logs.

Aurangabad.

The country around Aurangabad town most vividly brings home, even to a casual observer, the nature and sequence of the Trap flows. The horizontality of the flows with the different physical characters of the successive layers persisting at about the same M.S.L. in hills separated by valleys or ravines may be noted at a glance in all directions. In the Aurangabad caves, at the junction of the two Trap layers the difference in hardness in the upper and lower layers are strikingly illustrated. In the massive figures carved in the caves, the lower softer Trap has crumpled away, obscuring the details of the carving, whereas, the upper harder Trap preserves all the details of the carving intact.

A few bore wells examined in Besonji's factory may be briefly described here. Two bore holes have gone to a depth of about 300′ each. Neither of them give adequate water supply and the owner considers them a failure as they do not yield water for even three or four hours in summer. It was elicited from the agent that the second bore hole was put down, not with the idea of supplementing the yield of the first well which though 294 ft. deep had given no yield, but in the hope that the second well would afford a better recuperation. Why, when the first bore had not struck sufficient supply at 294 ft. it was not continued, and what the reason was for presuming to obtain any supply from another bore of equal depth alongside, is not understood. The necessity of seeking geological advice in all such undertakings to direct efforts in the right direction may be realised from this instance. There seems to be some belief based on some remark of Dr. Mann that if water is not found within a depth of 300 ft. in the Deccan Traps, the bore should be

abandoned. The sooner this hard and fast rule is discarded the better. Evidently Dr. Mann's remarks must have been misunderstood; but many wrong ideas were in circulation, due to belief in patent water-finder machines and the wrong diagnosis of water diviners whose lack of knowledge of geology combined with the erratic behaviour of the implements employed led to much confusion of ideas. The difference between the levels in the two places instanced above is just as much as about 12′, but here, it hardly makes any difference in the story as the cores continue to be of hard rock. An Isler core drill was used for drilling and the core was examined from the successive levels.

The following record from the boring mistry's log book summarises the nature of the core in the locality :—

1′— 6′ Mooram.
6′—294′ Hard rock.

The cores from the bore holes corroborate the records. There are in the hard layers some comparatively soft types between 120′ and 140′. The Agent of the factory said that at that depth some water was met with. The bore was carried to the present depths of 294′ without any improvement in the yield. From the above instances attention may be drawn to the following points :—

(*a*) Water is met within comparatively softer strata of the Traps.

(*b*) The popular notion that, merely by increasing depth, the recuperation may increase, is fallacious in the Trap area, and no adequate supply will be obtained until one of the various types of porous layers is pierced.

In the same factory, there were two other bore wells that had gone to a depth of 70 ft. and they were also unsatisfactory, as, in summer the yield of water is very poor. If the principles underlying the water bearing conditions in the Trap area had been understood, the expense of the second bore hole would never have been incurred, but the first

would have been deepened until some porous strata was encountered and that is the only hope the owner has of obtaining adequate supply. The chances are in his favour if deepening is undertaken in the deeper well. If the geological succession with the respective thickness of the Traps are first determined from natural cuttings, and this sequence studied with reference to the M.S.L. of the perennial wells in the area, it would be easy to specify the probable M.S.L. at which water may be expected.

PARBHANI DISTRICT.

Sailu.

Contrary to the conditions pertaining to Aurangabad where the hard Traps seem to persist to a great depth, Sailu is favoured with good water bearing strata within about 130′ from the ground level. Hence, bore-wells are numerous and popular at Sailu. The general ground level at Sailu may be taken as approximately about 1400′ M.S.L.

The following log of the well bored under instructions from the Railway Engineer, District No. 2, is of interest :—

0′ 7′ B.C. Soil.
7′ 50′ Pale and redmooram (Zeolitic).
50′ 70′ Hard mooram.
70′ 91′ Red hard mooram (Zeolitic). (This layer is claimed to be the aquifer).

The fact that a hardened red or pink zeolitic mooram layer acts generally as an aquifer was brought out in the section on Deccan Traps in Vol. II, pt. ii to which reference was made in the opening of this note.

From the above data, it is seen why bore wells have been successful in and around Sailu. Four or five wells sunk to a similar M.S.L. tap the same aquifer and afford a good perennial supply.

Partur, Ranjan and Paradgaon. Parbhani District.

The following interesting example between Sailu and Jalna demonstrates the nature of the distribution of water in the Trap formations.

At Partur (M.S.L.—1520 ft.) a bore was put for water and *at 48 ft. from ground-level good 'springs' were met with.* Between 48 ft. and 63 ft. the drill had to penetrate hard rock and between that and 100′ there was comparatively softer rock which gave a copious water supply. Near Ranjan Railway Station, about 8 miles N.W. of Partur Railway Station is a masonry well which has been sunk to a depth of 35 ft. and its recuperation is poor. The general ground level in the neighbourhood of the well is about 1520 ft. A well at Paradgaon 3 miles S.E. of Ranjan which is 30 ft. in depth gives very good supply of water. The general ground level at Paradgaon is about 1500′. People were wondering why the 35 ft. deep well near Ranjan Railway Station should be failure whereas, the Paradgaon well just 30 ft. deep should give a good supply. On examination of the above data, it is seen from the bore hole record at Partur that at a depth of about 48′ from the ground level is an aquifer. Reducing the levels, at about 1470 ft. M.S.L. (1518′—48′) there seems to be an aquifer. The well at Ranjan Railway Station, (M.S.L. 1520′) does not appear to have gone to this level as deducing the M.S.L. to the bottom of the well, we only get 1520′—35′=1485 ft. M.S.L. At Paradgaon M.S.L. (1500′) the well has tapped the 1470′ aquifer going 30′ deep with the result that its recuperation is good. It is reasonable to assume that all these places being within a radius of about 8 miles, show one type of sequence and all tap the same aquifer. Thus, once the M.S.L. of the aquifers in an area is known, water finding is reduced to a rule of thumb. In all probability, had the Ranjan well been sunk down to tap the 1470′ aquifer, its yield would perhaps have been equal to that of the other wells.

Parbhani Town.

Parbhani Town affords a very striking example of how ignorance of geological conditions can lead to waste of money and bad results. Very near the Taluqdari is a bore-well which is said to have gone to a depth of 110′. This bore well yields a constant supply for a 2″ centrifugal pump driven by an oil engine. About 2 miles away, just outside

the town, a bore was driven to a depth of 250′ for the Town Water Supply, obviously with the notion that a deeper well will yield better supply. This 250′ bore well, as testified by the Asst. Engineer-in-charge of the Water Works, was a thorough failure, there being no yield even for an hour's pumping. A core drill was used for boring and the classification of the logs as given from the diary of the mistry (and generally corroborated from the core pieces lying in the vicinity) is given below.

0′— 2	Mooram.	
2′— 13′	Hard rock.	
13′— 44½′	Red zeolitic amygdoloidal rock.	
44½′— 66′	Hard rock.	
66′— 83½′	Lithomarge (friable).	
83½′—114½′	Hardened zeolitic rock. This layer gave the water supply.	
114½′—208′	Dark, very hard, fine grained Trap.	All this boring was waste of money.
208′—211′	Friable mooram.	
211′—250′	Dark, very hard, fine grained rock.	

It is hardly necessary to point out here that the successful bore well near the Taluqdari stopped at 110 ft. in the comparatively softer, water bearing strata, whereas, this well going deeper, encountered adverse conditions and penetrated hard barren, fine-grained Trap which must have been most costly to bore through and gave not a gallon of extra water supply to the bore-hole.

Conclusion.

In the above paragraphs, it has been attempted to show that the conclusions arrived at from observations in Gulbarga and Osmanabad Districts regarding the distribution of underground water in Deccan Traps and verified from detailed field-work in parts of those districts find further corroboration even from the meagre data that could be collected from bore-hole records in several places in the Aurangabad and Parbhani Districts of His Exalted Highness the Nizam's Dominions, which are composed of the Deccan

Traps. It is hardly necessary to warn that the generalisations may have certain exceptions as indeed every generalisation must have. Adequate evidence has, however been adduced confirming the broad conclusions.

Note by Special Officer.

Officers in charge of Departments of His Exalted Highness' Government and the Agent of the Nizam's State Railway are invited to apply in this connection for the services of the Hyderabad Geological Survey Department, which to save time had better be made through the Financial Secretary.

The Special Officer again repeats his appeal made in Vol. II, pt. ii p. 103 and appendix I for information on this subject and an earnest request to officers of the Agricultural Department, the Public Works Department and Nizam's State Railway to preserve their cores or borings so that invaluable geological information on this most important subject can be scientifically correlated.

Photo 1. Ribbed weathering shown by acidic granodiorites. Kallur.

Photo 2. Pitted and ribbed weathering of intermediate granodiorite, [illegible]

[illegible]

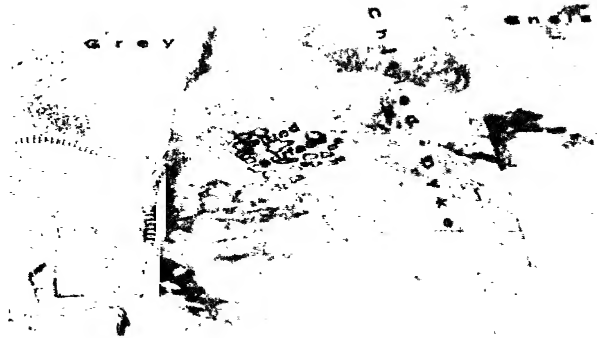


Photo 4. Chilled dolerite dyke. [illegible] hill.

Traps. It is hardly [illegible] sations may have certain [illegible] sation must have. Adequate [illegible] adduced confirming the [illegible]

[illegible]

Officers in charge of Departments [illegible] ernment and the Agents of the [illegible] apply in this connection for the [illegible] Survey Department, which [illegible] the Financial Secretary.

The Special Officer [illegible] ii p. 103 and appendix [illegible] request to officers of the [illegible] Department and [illegible] so that [illegible] can be [illegible]

Photo 1. Ribbed weathering shown by acidic granodiorites. Kallur.

Photo 2. Pitted and ribbed weathering of intermediate granodiorite. Ganekal.

Photo 3. Granodiorites intruded and mantled by white pegmatite. Partipalli.

Photo 4. Chilled dolerite dyke. Manvi hill.

Photo . White pegmatites capping granodiorite. Tursandiddi.

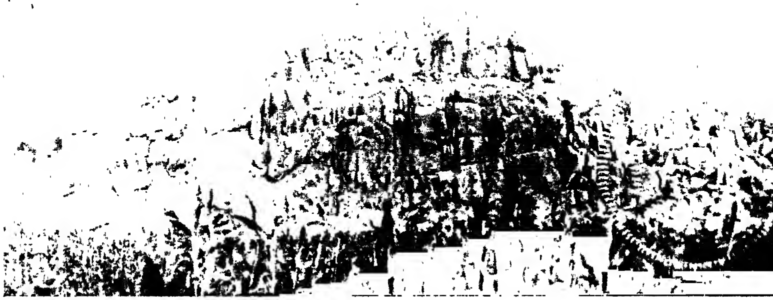
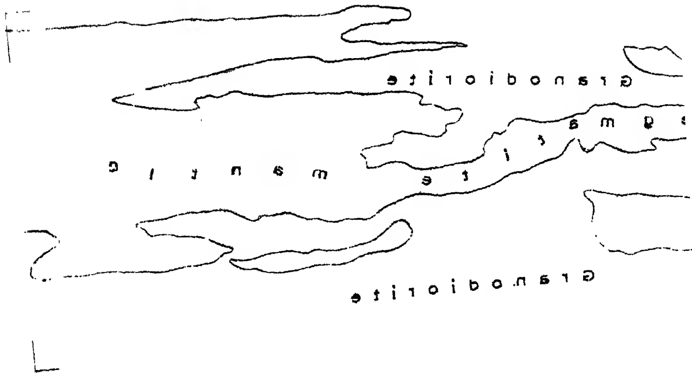
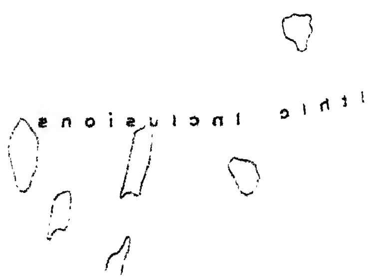


Photo 6. Granodiorite hill. Nilagal.

Photo 7. Xenolithic dyke. 2 miles south of Kurdi.


Granodiorite
Granodiorite


lithic inclusions

photos 5-7)

Photo 5. White pegmatites capping granodiorite. Turkandoddi.

Photo 6. Granodiorite hill. Nilagal.

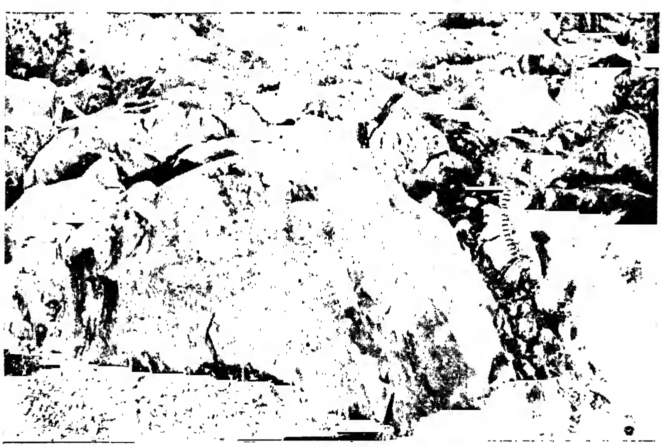


Photo 7. Xenolithic dyke. 2 miles south of Kurdi.

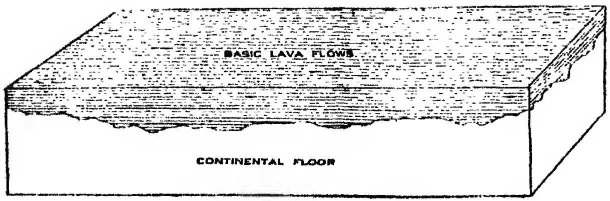


Photo 8. Hypothetical diagram suggesting original horizontality of basic lava flows (Dharwars) resting on a Continental floor.

Photo 9. Diagram suggesting the crumpling of basic lava flows (Dharwars) under thrusts of emplacing batholith.

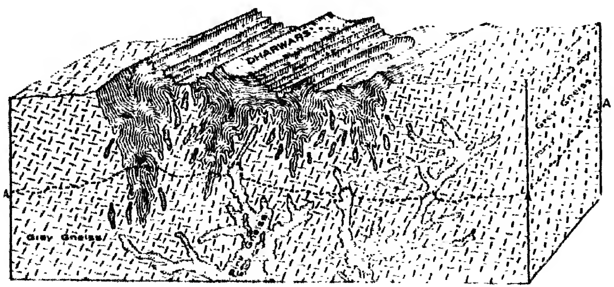


Photo 10. Diagram suggesting further crumpling of Dharwars and differentiation of the batholith into the Grey and Pink Series of Crystalline Complex.

Photo 11. Diagram suggesting existing geological features resulting from erosion down to line AAA in Photo 10.

PLATE V.
(Photos 8-11)

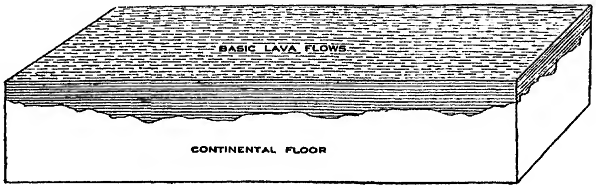


Photo 8. Hypothetical diagram suggesting original horizontality of basic lava flows (Dharwars) resting on a Continental floor.

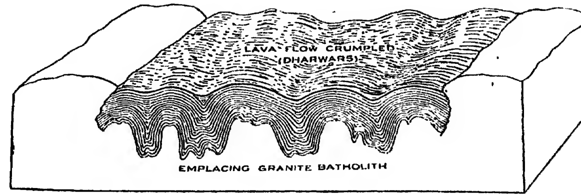


Photo 9. Diagram suggesting the crumpling of basic lava flows (Dharwars) under thrusts of emplacing batholith.

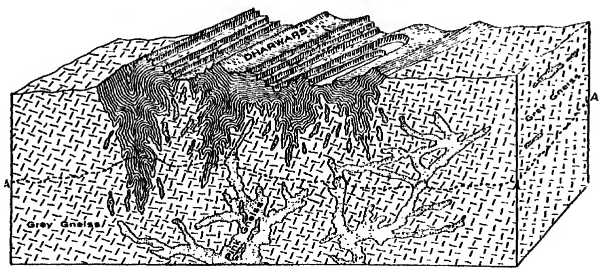


Photo 10. Diagram suggesting further crumpling of Dharwars and differentiation of the batholith into the Grey and Pink Series of Crystalline Complex.

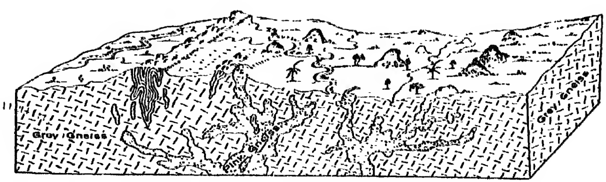


Photo 11. Diagram suggesting existing geological features resulting from erosion down to line AAA in Photo 10.

Photo 12. Scraping Saline efflorescence, bank of Tungabhadra irrigation canal-about 50 yards from the river. Rajavoli.

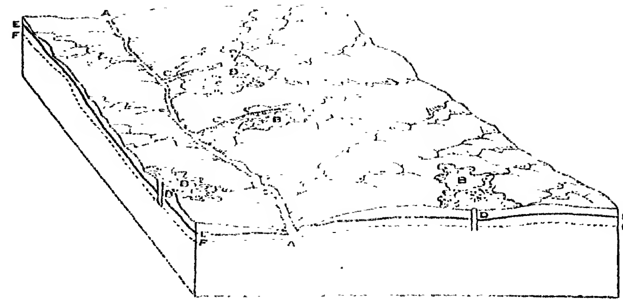


Photo 13. Block diagram to illustrate how salinity due to superficial causes might be removed by deep ditches or by pumping.

[illegible]

Photo 15. Dolerite dyke [illegible]

Photo 12. Scraping Saline efflorescence, bank of Tungabhadra irrigation canal-about 50 yards from the river. Rajavoli.

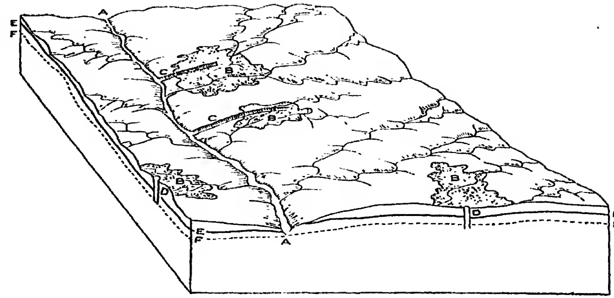


Photo 13. Block diagram to illustrate how salinity due to superficial causes might be removed by deep ditches or by pumping.

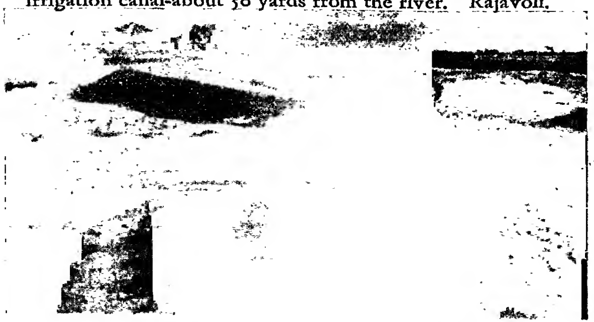


Photo 14. Erosion of black cotton-soil exposing the underlying yellowish white impervious calcareous

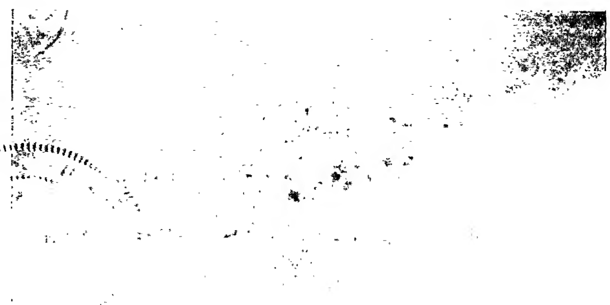


Photo 15. Dolerite dyke. Bagalwad.

ABBREVIATIONS USED

1.	Hornblende	H.
2.	Quartz	Q.
3.	Biotite	Bi.
4.	Ilmenite	Il.
5.	Orthoclase feldspar	Orth.
6.	Plagioclase feldspar	Pl.
7.	Apatite	A.
8.	Kaolinised feldspar	Kaol.
9.	Sphene	Sp.
10.	Feldspar	Feld.
11.	Magnetite	M.
12.	Epidote	Ep.
13.	Augite	Au.

1. Coarse-grained granodiorite. G[illegible]

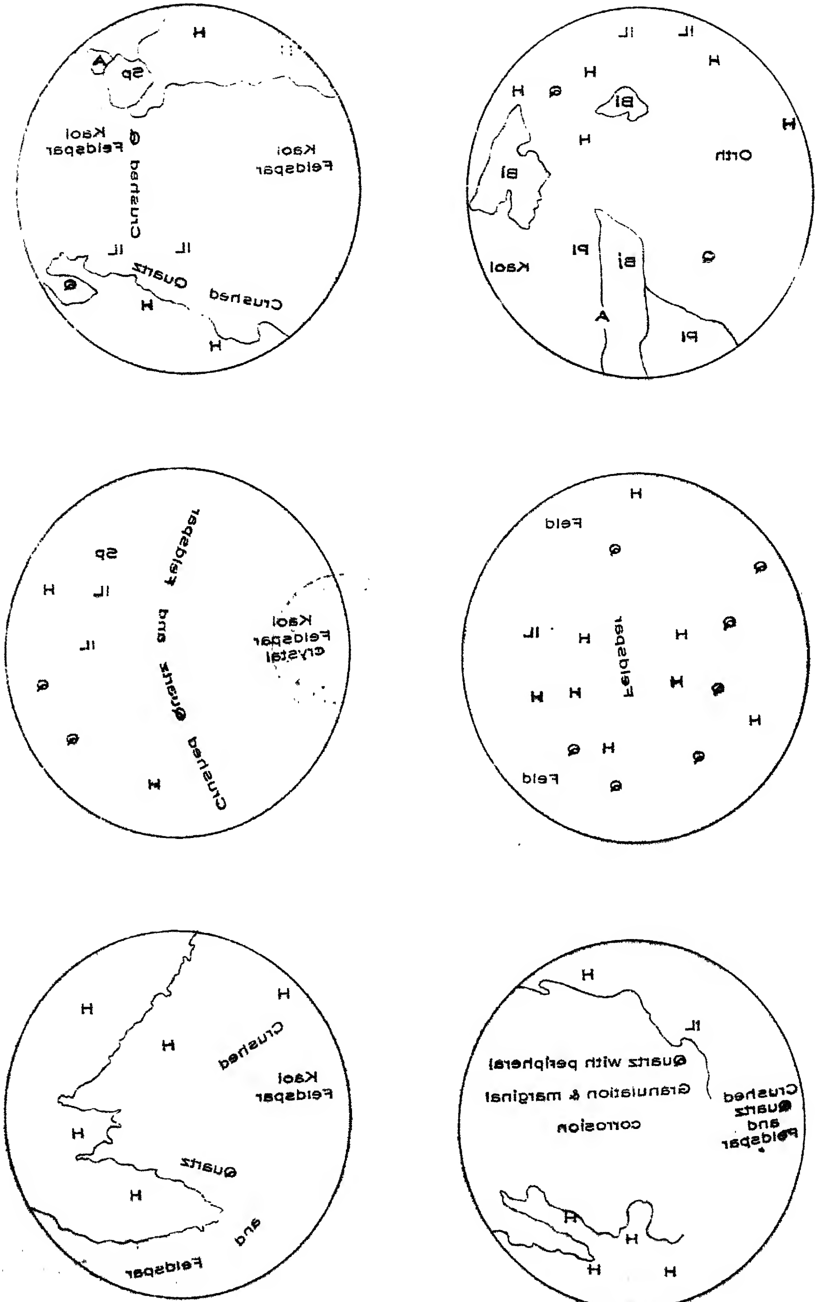
2. Medium-grained granodiorite. Tettmendoddi.

3. Fine-grained granodiorite. Gudawaram.

4. Granodiorite porphyrite. Kallur hill.

5. Acid variety. Kalmali.

6. Intermediate variety. Ga[illegible]



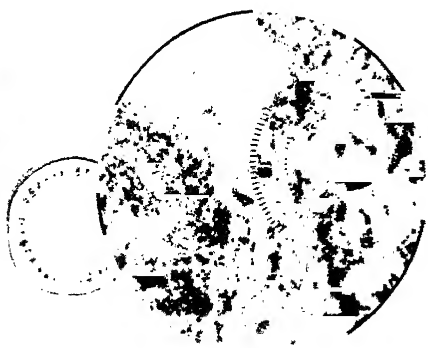
H
A
Sp
Kaol Feldspar
Kaol Feldspar
Crushed
IL
IL
Quartz
Crushed
H
H
IL
IL
H
H
H
Bi
H
Orth
Bi
Pl
Bi
Kaol
A
Pl
Feldspar
Sp
IL
H
and
IL
Kaol Feldspar crystal
Quartz
Crushed
H
Feld
IL
H
Feldspar
H
H
H
H
H
H
Feld
H
H
Crushed
Kaol Feldspar
H
Quartz
H
and
Feldspar
H
IL
Quartz with peripheral
Granulation & marginal
corrosion
Crushed
Quartz
and
Feldspar
H
H
H
H

Magnification 60. (Micro-Photos 1-6)

1. Coarse-grained granodiorite. Gandhalu.

2. Medium-grained granodiorite. Tottinendoddi.

3. Fine-grained granodiorite. Gudawaram.

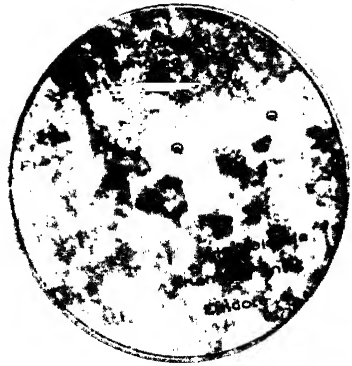


4. Granodiorite porphyrite. Kallur hill.

5. Acid variety. Kalmali.

6. Intermediate variety. Gabur.

7. Basic variety. Pa...



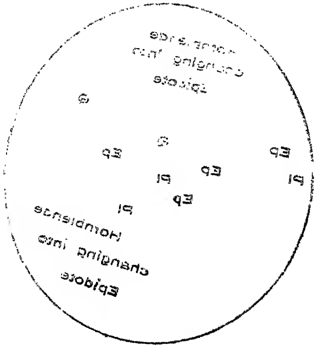
8. Epidotised rock. S.E. of Kallur.

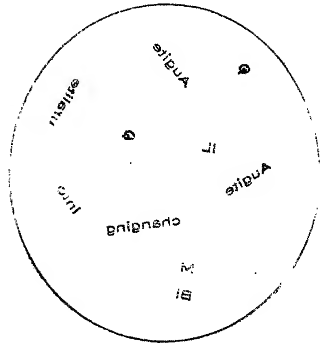
9. Epidote hornblende rock. W.N.W. of Dinni.

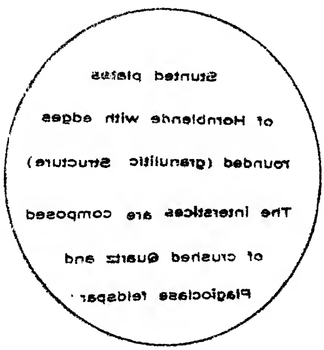
10. Granulitic schists. Wandalli.

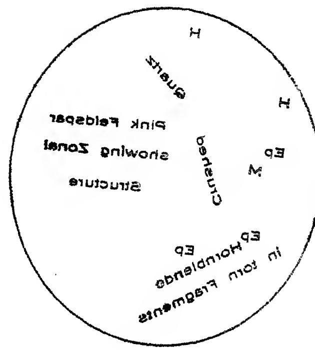
11. Dolerite dyke. Kurdi.

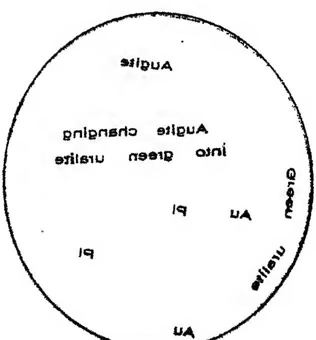
12. Epidiorite dyke. Sas...

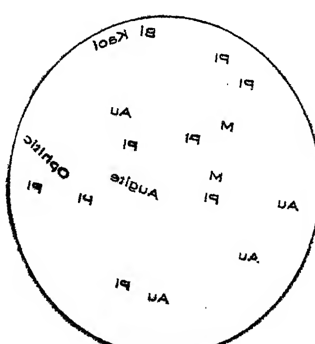

Hornblende changing into Epidote
Ep
Ep
Ep
Ep
Pl
Pl
Pl
Hornblende changing into Epidote


Augite
uralite
IL
Augite
changing
into
M
Bl


Stunted plates
of Hornblende with edges
rounded (granulitic Structure)
The interstices are composed
of crushed Quartz and
Plagioclase feldspar.


H
Quartz
H
Pink feldspar
showing Zonal
Structure
Crushed
Ep
M
Ep
Hornblende
Ep
in torn Fragments

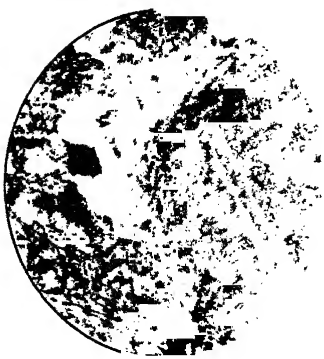

Augite
Augite changing
into green uralite
Green uralite
Pl
Au
Pl
Au


Bl Kaol
Pl
Pl
Au
M
Pl
Pl
Ophitic
Augite
M
Pl
Pl
Pl
Au
Au
Pl
Au

Magnification 60. (Micro-Photos 7-12)

7. Basic variety. Partipally.

8. Epidotised rock. S.E. of Kallur.



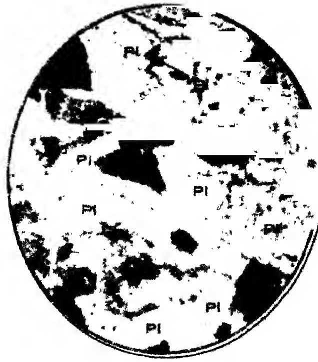
9. Epidote hornblende rock. W.N.W. of Dinni.

10. Granulitic schists. Wandalli.

11. Dolerite dyke. Kurdi.

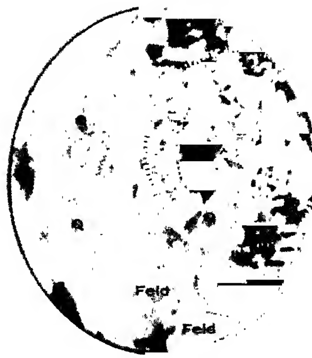
12. Epidiorite dyke. Sasnur.

13. Xenolithic dyke.



Uppal.

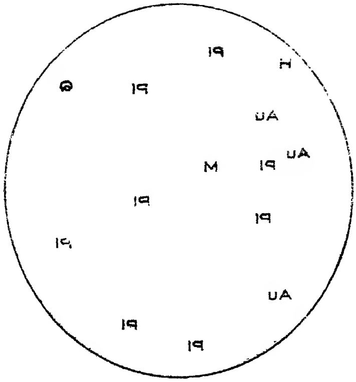
15. Ilmenite changing into Sphene

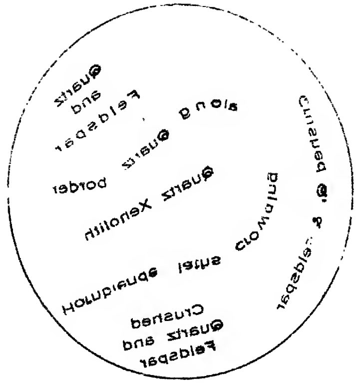


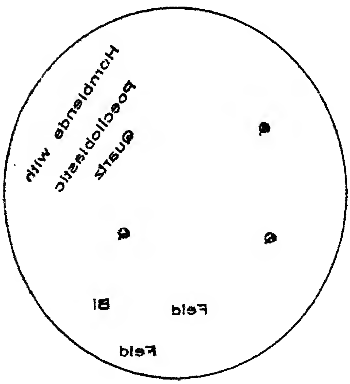
in hornblende.

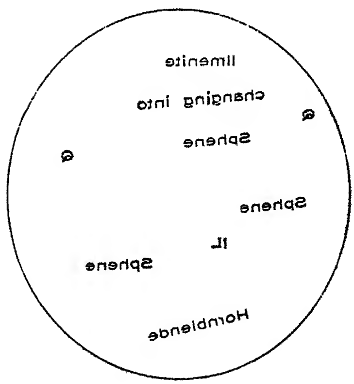
17. Hornblende changing into biotite.

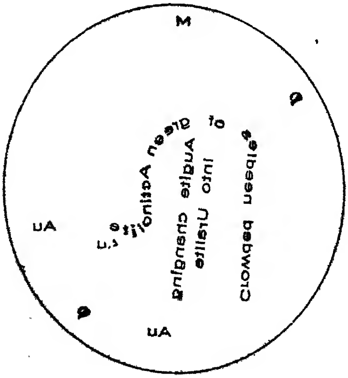
18. Augite changing into uralite.

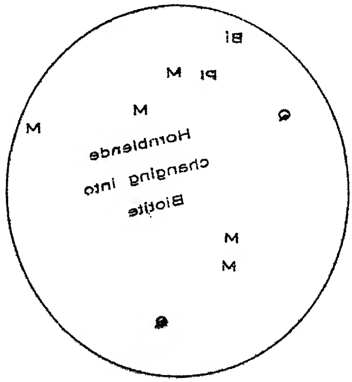

pl
I
Q
pl
Au
Au
M
pl
pl
pl
pl
Au
pl
pl


Quartz and Feldspar
along Quartz border
Quartz Xenolith
Hornblende laths Crowding
Crushed Q & Feldspar
Crushed Quartz and Feldspar


Hornblende with Poeciloblastic Quartz
Q
Q
Q
Bl
Feld
Feld


Ilmenite changing into Sphene
Q
Q
Sphene
IL
Sphene
Hornblende


M
Q
of green Actinolite
Augite changing into Uralite
Crowded needles
Au
Q
Au


Bl
pl M
M
M
Q
Hornblende changing into Biotite
M
M
Q

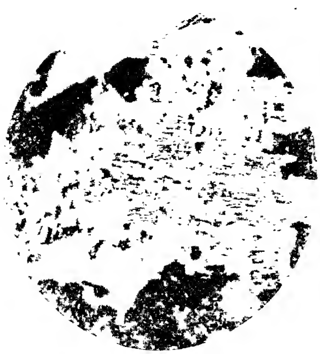
Magnification 60.

13. Xenolithic dyke. Aruvalli.

14. Porphyritic dyke. Uppal.

× 150
15. Ilmenite changing into Sphene.

16. Poeciloblastic structure in hornblende.



17. Hornblende changing into biotite.

18. Augite changing into uralite.